THE CHINESE UNIVERSITY OF HONG KONG

FACULTY OF MEDICINE

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THE EFFECT OF CORRECTIVE SPLINTAGE ON FLEXION CONTRACTURES OF RHEUMATOID FINGERS

BY

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A dissertation submitted in partial fulfilment of the requirements for M. Phil.
(Clinical & Pathological Sciences, Graduate School)

July 1993

Dedicated to Hercy, Lawrence, Fiona and Mum

Acknowledgements

I wish to thank Professor P. C. Leung, Chairman, Department of Orthopaedics and Traumatology, Prince of Wales Hospital for his encouragement, advice and support towards my MPhil programme of study. I also wish to thank Dr. King, Head, Department of Rehabilitation Sciences, Hong Kong Polytechnic for his support and approval on my MPhil programme.

I am in debt with Dr. L.K. Hung and Dr. Arthur Mak for their dedication on the supervisory work. Without their input, the project would not be finished. I wish to thank Dr. J. Hui, Department of Orthopaedics and traumatology, Prince of Wales Hospital for his advice on the statistical analysis of the study.
Special thanks to Dr. W. S. Wong for his great support on my project and his kindness to allow me to attend his rheumatology clinic at Tang Chi Ngong out-patient clinic to collect suitable subjects. Without his support, the study could not proceed. Thanks to Ms. Sze and Wendy, nursing staffs at the clinic for their special arrangements for me during my attachment. Special thanks to Dr. So Yat Cheung and Dr. Cheung Wun Po, consultants, department of Orthopaedics, Queen Elizabeth Hospital, for their approval to release their clients for my study.

Thanks to Mr. Simon Wong, Senior occupational therapist i/c, Prince of Wales Hospital and his staff for the continuous support by allowing me to conduct the study at his centre. Special thanks to Mr. Hercy Li, Senior Occupational Therapist, Ruttonjee Hospital by permitting me to carry out my study at his centre. Thanks to Mr. Leung Kwok Fai, Department Manager, Occupational Therapy Unit, Queen Elizabeth Hospital and his staff for their support by referring suitable clients to me.

I must also thank Mr. Fung Chi Fai and Mr. Wong for their technical support during the course of work. Special thanks to Dr. Arthur Mak, Mr. E. Tam, Mr. Siu and staffs at Rehabilitation Engineering Centre for their technical support on developing the assessment tools. I must also thank Mr. Simon Tsang for his assistance in the graphical presentation of the thesis.

Specials thanks to my students Edward Chan, Meaki Chan, Sanny Cheng and Rosanna Kay for their kind assistance in conducting the Jebsen hand functions test on normal subjects. I must also thank all the staffs at St. James Settlement who are involved in the Jebsen study for their kind assistance.

I would not forget the spiritual support from staff of the Occupational Therapy Section, Mrs. K. Sinclair, Mrs. P. Jenks, Ms. Susanna Chow and Mr. Andy Chung.

Last but not the least, I wish to thank all the rheumatoid arthritic clients involved in my study for their co-operation and compliance during the study. Special thanks to Leung Siu Ying for her encouragement during the course of the study. I also thank the volunteers at the Hong Kong Polytechnic for their participation as subjects in data collection of the local norms of the standardised hand functions test.

Abstract

Rheumatoid arthritis (RA) is a chronic inflammatory disease which affects all joints and movements of the human skeletal system particularly over the small finger joints of the hand affecting hand function. Often, patients have a lot of functional disabilities due to repeated exacerbation and remission. Occupational therapists are involved in helping these patients to achieve maximum function and to prevent deterioration. One treatment modality for intervention is splinting.

This study focuses on the effectiveness of corrective splintage in the management of flexion contracture of the proximal interphalangeal joints of RA patients. In view of the subjectivity of common assessment methods adopted by occupational therapists and patients, there arises the need to develop standardised assessment methods in order to quantify the effect of therapeutic intervention programme. This study aims to develop a comprehensive evaluation system on hand functions of rheumatoid arthritic patients. The study also focuses on the biomechanical analysis of different splint designs and their effects on flexion contracture.

A local study on Jebsen Hand Functions test was conducted in January, 1991. The Jebsen Hand Functions test was adopted and translated in Chinese for the purpose. Fifty five normal subjects and twenty nine rheumatoid arthritic patients volunteered to be the subjects for the study. Each subject was assessed using the standardised procedure on the time performance of each subtest including writing, turning cards, picking up small objects, simulated feeding, stacking chess, picking up large light cans and picking up large heavy cans. The measurement of power grip, pinch grip, lateral pinch grip and chuck grip were also conducted. The results reflected that the mean values collected locally have strong correlation with the US norms collected in 1969. The rheumatoid group showed an average longer time to perform all the subtests. Among the rheumatoid group, there is a strong correlation between their functional class and the score of the hand function tests.

For the measurement of grip strength, a comparative study on the effect of two assessment devices: the REC grip analyzer and the Jamar dynamometer was conducted. The result reflected that the REC grip analyzer is more sensitive in measuring the grip strengths ranging from 0 to 5 kgf and proved to be more effective for use in rheumatoid arthritic patients who have, in general, very weak grip strengths.

A thorough literature review of various dynamic finger extension splints and static finger extension splints was conducted before the selection of splints for study. Two splints: the Capener splint(dynamic finger extension splint) and the Belly Gutter splint(static finger extension splint) were then analyzed from a biomechanical perspective. The comparison included the force distribution, the weights and the contact area of each splint. The actual force exerted to counteract the flexion contracture was measured by the pressure censor connected to the oscilloscope. The changes in voltage from the pressure censor were calibrated by the loading system in terms of newtons vs changes of millivolts. As a result, the force distributed on individual splints was compared. The laboratory testing was conducted prior to the main study.

A pilot study was conducted using four patients who suffer from rheumatoid arthritis and who have flexion contracture at the proximal interphalangeal joints. The results reflected that the clients with splints intervention showed significant improvement in active extension of the affected fingers. Clients with the capener splint had shown a better result than clients with the belly gutter splint intervention. The methodology was modified and the main study took place from May, 1992 until December, 1992. Twenty four rheumatoid arthritic patients were carefully selected and were paired according to functional classification, age and year of onset. Initial assessments were conducted with the assessments of active range of motion, measurements of power grip, chuck grip, lateral pinch grip and pinch grip(between affected finger and thumb), assessments using Standardised hand function test, pain level and ADL performance from patients feedback. Similar assessment procedures were repeated on the 24 clients for documentation of any changes during the control period. Then, for group 1 the dynamic finger extension splint was fabricated to each client whereas for group 2, the static belly gutter splint was fabricated. Each client was instructed on the proper wearing methods and regimes. After six weeks of intervention, the clients were re-assessed separately. The results were then compared with the initial assessment. The mean difference between the initial assessment, the assessment before intervention and after intervention are compared. It was found that there is a significance difference in the results before splint intervention and after intervention in both group 1 and 2. Both groups showed improvements in active range of motion, grip strengths and hand function tests. However, when comparing the two splints, there showed significant difference in active range of motion(both in flexion and extension) of the affected finger. Group 1 with the dynamic splint intervention showed a better result than group 2 clients with static splint intervention. There is also a difference in the pinch strengths in the two groups. Group 1 clients showed an increase in pinch after splint intervention. Although there is no significant difference in hand function performance using the Jebsen Hand Function test, there is an improvement of the dexterity at the affected finger in both group 1 and group 2.

This study indicates that corrective splinting is effective in correcting flexion contracture of the PIP joint. The dynamic finger extension splint showed a better correction effect than the static belly gutter splint. The dynamic splint is also effective in improving the pinch strengths of the affected finger. This point is often neglected in the management of rheumatoid hand. The dexterity skills of the affected finger have shown improvement after the splint intervention. The limitation of the study is that the number of subjects collected is too small to produce a generalised statement of effectiveness. Also the effect of improvement of one single joint may not produce a significant change in the overall improvement in hand functions. However, it is a very promising study that will facilitate the investigator to broaden the scope of treatment intervention for the whole hand based on the biomechanical principles adopted for a singe joint.

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Chapter One
Introduction

1.1 Introduction

Rheumatoid arthritis is the most common chronic inflammatory disease of joints characterised by remissions and exacerbations. It is a systemic disease and in some clients may involve the lungs, blood vessels, heart or eyes(Melvin, 1982).

The prevalence of rheumatoid arthritis in the United States population is about 3% with three women affected for every one man, but only 2 /1000 of the population require sustained treatment. However, there is as yet no extensive study on the prevalence of the disease in Hong Kong. The peak age of onset is around 40 years (Dieppe, 1985).

For chronic arthritic patients, after several years of persistent synovitis, joint destruction, instability and deformity ensue. Deformities are caused by disruption and dislocation of tendons as well as erosion and destruction of cartilage and bone of the joints. Loss of ability to carry out the necessary tasks of daily living and dependence on others are major concerns of the patient at this stage of the disease. Their rehabilitation is a significant social, economic and personal problem.

Occupational therapists in Hong Kong have been involved in the rehabilitation of patients with rheumatoid arthritis. Proper joint mobilisation programmes, instructions on joint protection techniques, provision of splints, home visits and advice on home adaptations and aids are often prescribed for patients suffering from chronic disabilities.

One of the conservative methods in management of joint contracture and deformity is the use of elastic splints and traction (Curtis, 1990). Provision of resting hand splints have been found effective in the early stage of disease to rest the inflamed joint and provide pain relief(Rostein(1965), Flatt(1963) & Shalet(1969). However, there are very few studies which focus on the effect of corrective splintage in prevention and correction of deformities for rheumatoid patients. Curtis(1983) mentioned that elastic splints and traction should be used early in the course of disease and continuously; the amount of tension should not produce swelling. This is just a general statement. The design of corrective splints whether static or dynamic, the amount of traction and its effect on overall hand functions should be studied carefully. Previous studies (Convery, Conalty & Nickel (1967) found that complex splint designs involving multiple joints are not effective in the prevention of deformities and at the same time interfere hand functions. Simple splints addressing single joint problem may be more effective.

In Hong Kong, most occupational therapists show hesitation in providing corrective splints for RA patients with a view that the stretching force might create further damage to the joints. The amount of force is not measured and the effect cannot be predicted. Often the intervention is delayed, resulting in permanent deformities. Progression is insidious and the patient is often unaware of the deformity until one day the hand function is markly deteriorated.

One of the most common hand deformities is flexion contracture of the proximal interphalangeal(PIP) joint(Wong, 1990). It is the epicentre of the hand(Curtis, 1987). Any trauma or injury affecting the joint motion of the PIP joint will affect hand function.

S.H. Wu(1990) pointed out in his study that static inelastic corrective splints for flexion contracture of the PIP joint may be more effective than dynamic or elastic splints with rubber band or coil spring elements. In his study, he analyzed only the effect of static traction splint on hand injured patients without comparing its effect with the dynamic traction splint. In this study, the proximal interphalangeal joint (PIP joint) is selected for review and two types of corrective splints are chosen for comparative study.

On the other hand, the rheumatoid hand is difficult to assess objectively because of its multiple joints and multiple stages of involvement. Most of the currently available assessment tools give either an exaggerated or depreciated assessment. The assessment protocol varies among different clinical settings. Most assessment tools are not suitable for RA patients specifically. One common example is the use of Jamar dynamometer. Most therapists find difficulties of documenting any scores for RA patients due to their weak grip strengths. Some assessment procedures are not standardised and the results may be unreliable or biased. Therefore, a comprehensive study to develop an evaluation system is essential prior to the study of splint effectiveness.

1.2 Aims of study

On the basis of these reviews, the investigator will start this study by developing a hand evaluation system which includes measurement of joint range of motion, grip strengths, dexterity skills and pain assessment. Some common assessment tools are selected and compared for their effectiveness. The study therefore examines objectively the hand assessment for rheumatoid arthritic patients.

The study also aims at analyzing the effect of two types of corrective (one dynamic and one static) splints on the flexion contracture of the PIP joints in terms of grip strengths, range of motion and dexterity. The study focuses on whether prolonged stretching using a static splint is more effective than the intermittent stretching and exercise splint programme for the hand function. The splint design and traction force will be studied in detail. Joint compression force is also analysed.

As a summary, the following aims are identified:

a. to develop a comprehensive evaluation system for RA hand

b. to analyze mechanically two different splint design for the correction of Proximal interphalangeal joint flexion contracture

c. to compare the effect of two different types of corrective splints on the hand function of RA clients.

Chapter Two
Rheumatoid Arthritis

2.1 Definition

Rheumatoid Arthritis (RA) is a chronic inflammatory disease of the synovium with a course characterised by exacerbations and remissions. It is a systemic disease and in some clients may involve the lungs, blood vessels, heart or eyes. The course of the disease is often unpredictable and varies considerably from patient to patient. Patients suffering from rheumatoid arthritis often complain of multiple joint pain and stiffness.(Melvin, 1982)

2.2 Prevalence

There is no complete record on the prevalence of rheumatic disorders throughout the world. From the epidemiological surveys that have been done on selected populations, there is no relation to latitude , humidity or hours of sunshine. There is around 0.2% of the population in Japan diagnosed as rheumatoid arthritis as mentioned by Dieppe, 1986. However, there has been no extensive survey done in Hong Kong on the prevalence of the disease until now.

2.3 Aetiology

There is no aetiologic agent identified and Dieppe (1985) hypothesised that:

"A constitutionally suspectable individual encounters a triggering factor which produces joint inflammation. Instead of switching off in the normal way after the acute response, the inflammatory process becomes chronic and self-sustaining long after the initiating factor has disappeared."

2.4 Pathology

The synovitis of rheumatoid arthritis affects all joints, tendons and bursae that have a synovial lining (Dieppe, 1985). In the early stage, the synovial membrane is thickened (hyperplastic), hyperaemic, oedematous, and proliferates to form villi filling joint space.

At the junction with articular cartilage, pannus (granulation tissue) spreads out over cartilage. Pannus has vascular and avascular layers, both containing cartilage-derived cells, and separated from cartilage by fibrous layer. Where pannus replaces bone at articular margins, bone erosions occur. Pannus contains cytotoxic chemicals, released into the synovial fluid, which erode articular cartilage at pannus-cartilage boundaries. Synovial fluid becomes profuse, turbid and watery. Pannus then organises forming thick fibrous tissue leading to fibrous ankylosis of joint.

2.5 Clinical features of rheumatoid arthritis in the hand

Patients with rheumatoid arthritis usually complain of morning stiffness, symmetrical joint pain and swelling. The hands, wrists and feet are involved first (Hickling & Golding, 1984). Dieppe(1985) described the following clinical features on the hand:

Early stage

Wasting of small muscles is common in the early stage. There will be extensor tendon sheath swelling and fusiform swelling of the Proximal Interphalangeal(PIP) joints. The Metacarpal phalangeal (MCP)joint synovitis with filling-in of hollows between knuckles and flexor tendon synovitis are common. Prominent ulnar styloid may be present.

Late stage

a. Common hand deformities are seen including ulnar deviation of wrist, swan-neck deformities and boutonniere deformities at the fingers. Z- thumb and subluxation of Metacarpal phalangeal (MCP)joints are common with dropped fingers.

b. Grip strength will be decreased with poor thumb opposition. This will definitely affect hand function.

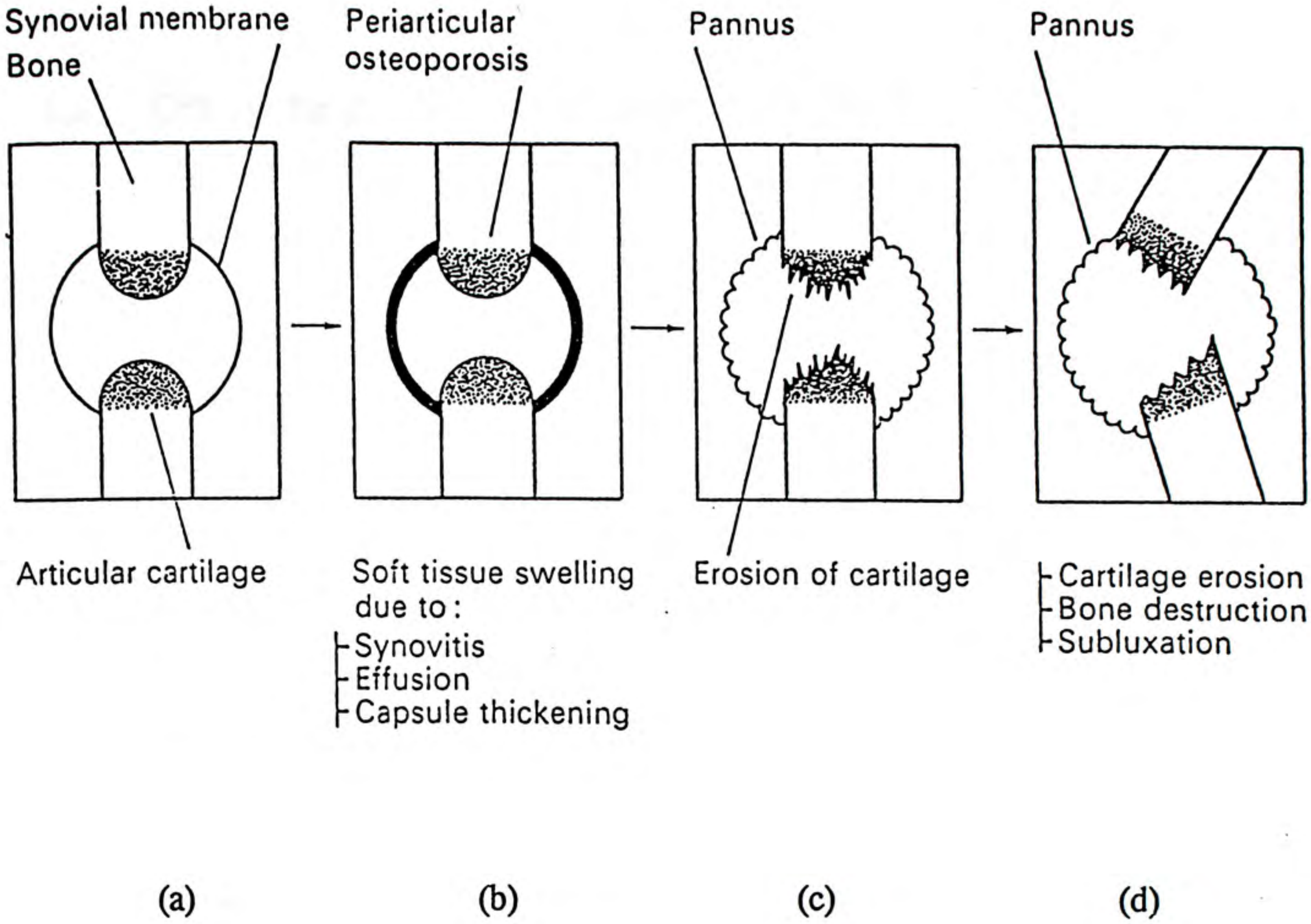


Fig. 2.1 Sequence of pathological changes. a. normal; b. early RA; c. established RA; d. chronic RA. (Golding D.N. 1989)

Fig. 2.2 Multiple joint involvement in Rheumatoid Hand

2.6 Criteria for the diagnosis of rheumatoid arthritis

The American Rheumatism Association (ARA) (1958-revised) has classified the various forms of disease as classical, definite, or possible, depending on the number of characteristic features present are described in appendix I.

However, since rheumatoid arthritic patients have multiple joint problems and other associated problems at various stages of the disease process, it is often very difficult to compare among the rheumatoid population. In 1949, Steinbroker established a criteria to assess functional status of patients with rheumatoid arthritis and Ropes (1958) modified it as follows:

CLASS	DEFINITION
I (early)	complete ability to perform all useful duties without handicap
II (moderate)	ability to conduct normal activities despite handicap of discomfort or limited motion of a few joints
III (severe)	only able to perform little or none of the duties of the usual occupation or self-care
IV (terminal)	largely or wholly incapacitated; confined to wheelchair or bed, with little or no self-care

TABLE 1 DEFINITION OF FUNCTIONAL CLASS IN RHEUMATOID ARTHRITIS

Other than subjective assessment on the levels of functions for each client, objective assessment such as using radiographic diagnostic tool is often used to define various stage of involvement. Ropes(1958) classifies the radiographic staging system to aid in the determination of the stages of the disease process.

STAGE	DEFINITION
I (early)	soft tissue swelling with no destructive changes, but osteoporosis may be present
II (moderate)	osteoporosis with or without slight subchondral bone and cartilage loss; soft tissue swelling or atrophy tenosynovitis and nodules may be present; no joint deformities or bone erosions
III (severe)	joint deformities such as subluxations,ulnar deviation, or hyperextension; extensive muscle atrophy with or without nodules or tenosynovitis; roentgenologic evidence of cartilage destruction, osteoporosis plus bony erosions, but without fibrous or bony ankylosis
IV (terminal)	criteria of stage III, plus fibrous or bony ankylosis

TABLE 2 RADIOGRAPHIC STAGING SYSTEM FOR RHEUMATOID ARTHRITIS(MODIFIED FROM ROPES,M.W.ET AL, 1958)

In this research study, it is important to define the rheumatoid arthritic subjects. Those diagnosed as classical and definite RA according to the ARA system are selected for the study. Their functional level should be either II or III according to Steinbroker's system of classification. The radiographic stage should be between II and III. The rationale for selecting these groups of clients is mainly to study how the splint affects the moderately involved rheumatoid arthritic patients rather than those patients who have the initial diagnosis of RA or in the other extreme at the terminal stages of the diseases. This also minimises the standard error in assessment of clinical effectiveness.

Chapter Three
Hand Deformities in Rheumatoid Arthritis

3.1 The Hand

3.1.1 Anatomy and kinesiology of the hand

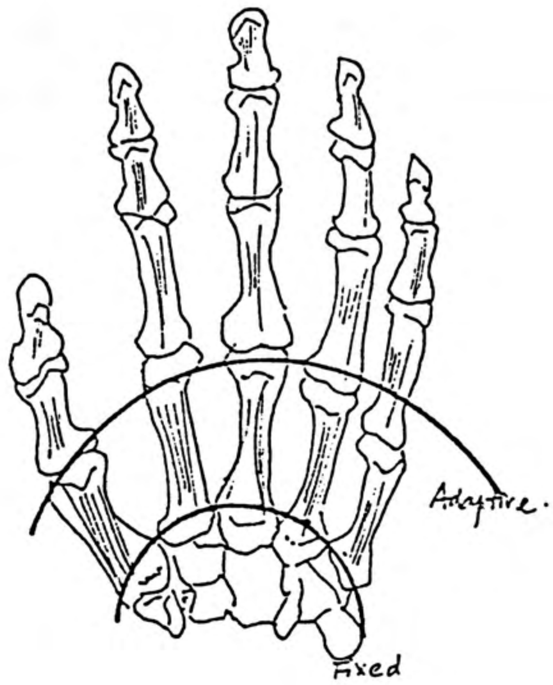
Chase (1990) states that the hand skeleton and associated ligaments constitute an architectural framework to allow the latitude of motion of the digits which is so characteristic of human hand function. The architectural units are divided into a fixed unit of the hand and mobile adaptive hand units.

The fixed unit of the hand, consisting of metacarpal 2 and 3 and the distal row of carpals, has very limited motion at the intermetacarpal joints and the second and third carpometacarpal joints and the second and third carpometacarpal joints. The distal row of carpal bones forms a stable, unchanging, transverse arch. The index and long finger metacarpals are fixed quite intimately to the distal carpal row, and together with it they form the fixed unit of the hand skeleton.

The adaptive units of the hand which move about the central I-beam consist of three elements which are in descending order of specialisation, the thumb ray, the index finger, and the fourth and fifth rays together with the long finger.

These foundamental anatomical structures allow the hand to carry out various functional movements in daily activities. Two distinct patterns of function identified by Napier (1958) are power and prehension.

A



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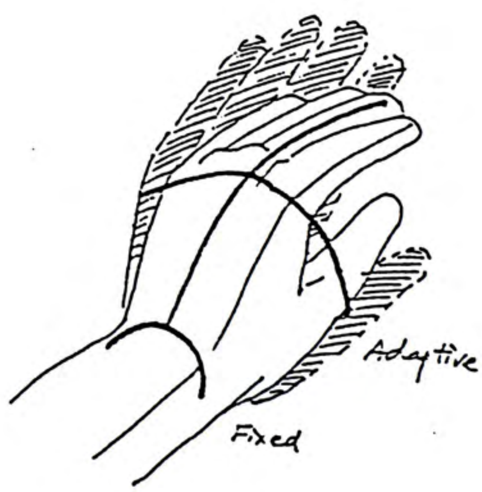


Fig.3.1 A) The fixed and mobile transverse arches of the hand.
B) Adaptive mobility at the level of the metacarpal heads, locus of the mobile transverse arch
(From Flynn JE & Jupiter JB: Hand surgery, 4th ed.)

3.1.2 Principles of Hand Kinesiology

Chase (1990) describes the movements in the hand as representing a complex series of muscular actions around multiple joint linkages. A muscle rarely acts independently to create movement. There are some principles governing the muscle tendon unit as described by Chase(1990) which are found useful in this study:

a. a muscle tendon unit acts on every joint between its origin and insertion.

b. The arrangement of muscles and tendons in relationship to a specific joint determines their effect on joint action within the range allowed by the joint configuration and ligamentous limitations.

c. The forces on a joint by a muscle depend not only upon muscle power but upon the combination of vectors affecting the joint at a given axis of motion.

d. The torque generated for rotary movement around a joint axis depends not only on the force generated by the muscle but by the lever arm or perpendicular distance from the axis or centre of rotation. This is popularly known as the movement arm.

3.1.3 Joints of the digits

Flatt (1983) states that the digital joints connecting the elements of the longitudinal arches all have the same basic anatomical form, which favours palmar flexion. Bowers (1987) refers to the interphalangeal joints as "hinge joints" which implies a stationary axis with motion perpendicular to the shaft of the phalanges. The joint apparatus consists of a capsule and a pair of strong collateral ligaments that pass around onto the palmar aspect to fuse with the sides of the accessory palmar plate. This plate consists of a tough fibrous portion in relation to the joint surfaces and a proximal membranous portion related to the metacarpal neck. The palmar plate accounts for the different incidence of involvement of extensor and flexor tendons by diseased synovium of the digital joints.

3.1.4 The Proximal Interphalangeal Joint

Curtis (1987) termed the proximal interphalangeal joint as the "epicentre" of hand surgery. He commented that there is nowhere in the human frame are anatomy and functions so interrelated as in this small joints. These statements correctly emphasise the importance of the proximal interphalangeal (PIP) joint and its anatomy in relation to hand function. This review gives the investigator the first bombardment of establishing the framework of this study: to analyse how the disease factors affect the structures and functions of this important structure.

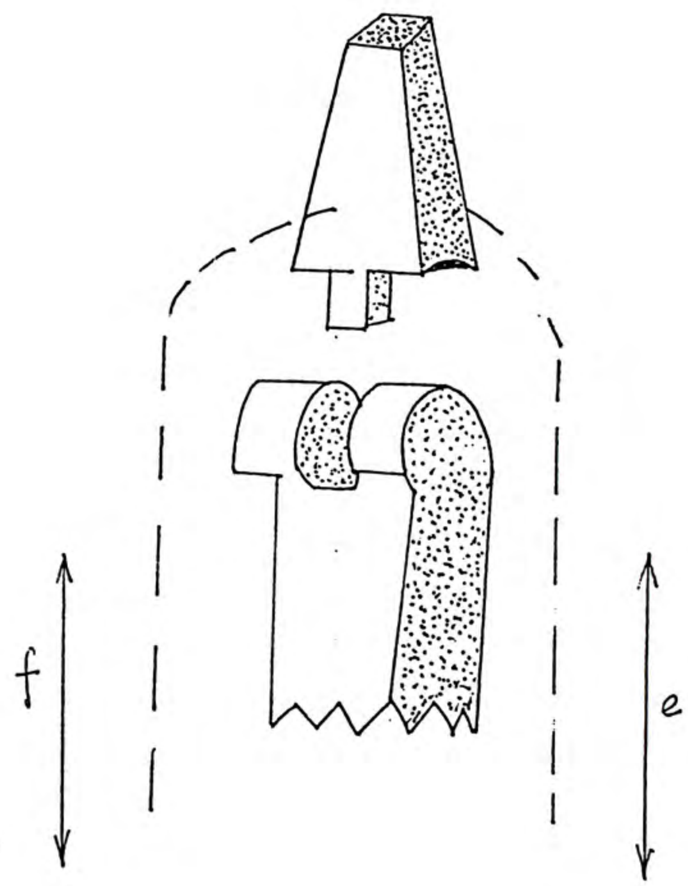


Fig. 3.2 A mechanical representation of interphalangeal joint motion as part of a pulley system. The distalward phalanx is part of a loop completed by flexor (f) and extensor (e) tendons. Lateral stability is obtained by a perfect fit of the tongue and groove plus tension within the loop system. (Kuczynski 1975)

3.2 The Rheumatoid Hand

3.2.1 Causes of hand deformities

Wilson, R.L.(1986) described that rheumatoid arthritis often begins in the hand, and upper extremity function can be seriously impaired with progression of the disease. The characteristic lesion is synovitis involving the joints and the extrinsic tendons. Joint effusion and inflammation cause the pain that begins the cycle of musculoskeletal problems associated with arthritis. The inflamed synovium increases pressure within the joint, placing tension on the capsule, stretching the ligaments and thin overlying tendon structures. The cartilaginous surface is chemically destroyed, and subchondral bone is eroded. Sometimes hypertrophic synovium may produce ischemic tendon changes.

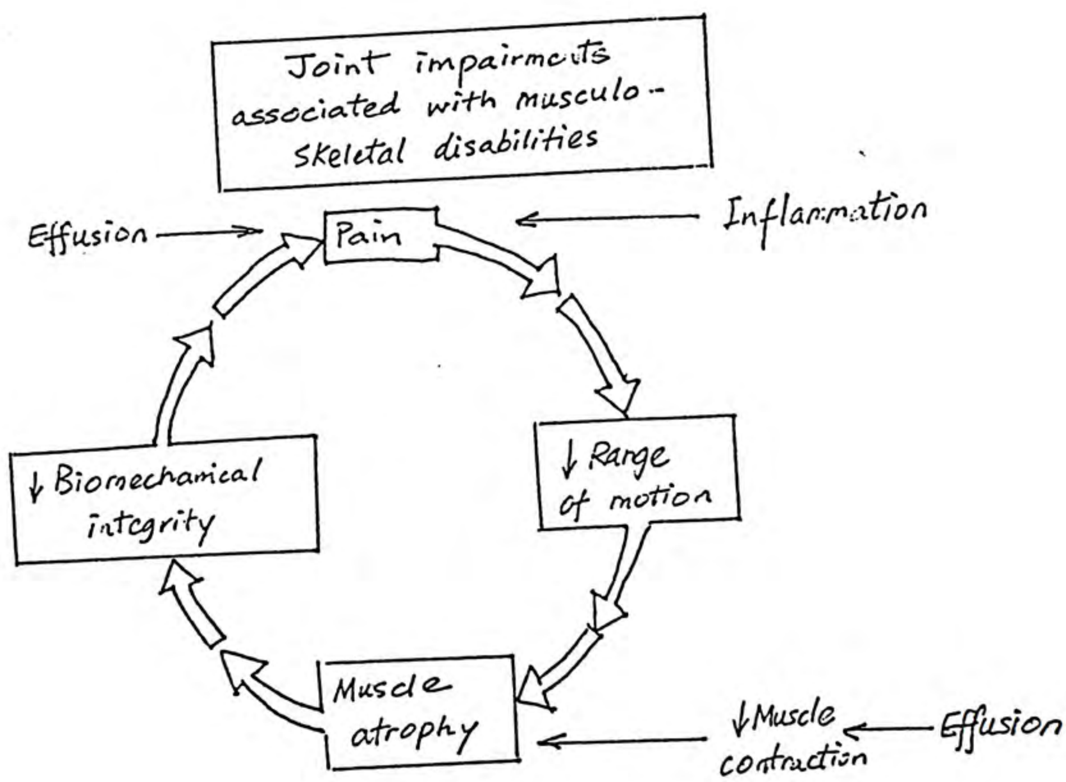


Fig 3.3 Diagramatic illustration showing how joint effusion and inflammation cause pain and the cycle of musculoskeletal problems (Hicks, 1987)

3.2.2 Common Hand Deformities in Rheumatoid Arthrities

Hand deformities due to chronic synovitis are common. The onset is often insidious and patients are often not aware of the gradual changes until one day he/she noticed significant deterioration in daily activities. Characteristically, the wrist, the metacarpal joints, proximal interphalangeal (PIP) joints, and the metacarpophalangeal (MP) joints and carpometacarpal joints of the thumb are commonly affected. The incidence of deformities at the wrist and the interphalangeal joints ranges from 63% to 85% as reported by Dieppe et al, 1985 in US population. Whether there is a cross cultural difference in the incidence of the deformities need further review.

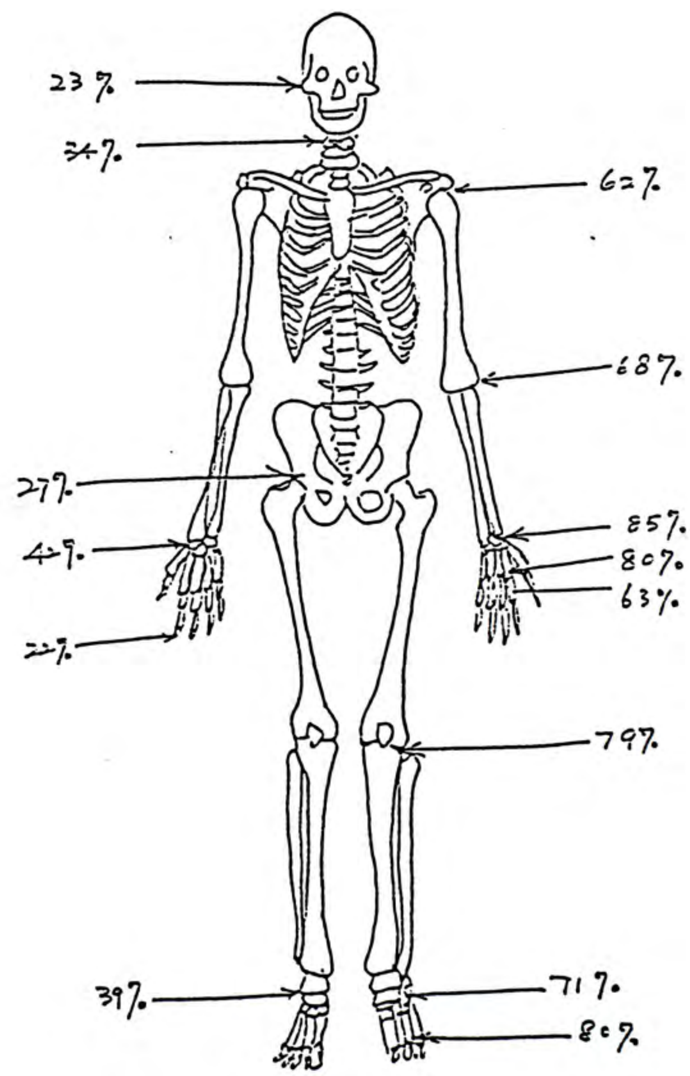


Fig.3.4 Distribution of joint involvement in rheumatoid arthritis (1985)

3.2.3 Incidence of Hand Deformities in Rheumatoid arthritis in Hong Kong

Professor McGrouther pointed out that the types of finger deformities are affected by the mechanical loading in daily activities during his presentation in the R.A. Symposium on Rheumatoid Arthritis (1990) organised by Hong Kong Society for Surgery of the Hand. The knowledge of the incidence of various types of deformities in the hand is very important before any research is conducted on the rheumatoid hand.

A retrospective study was carried out in 1990 among six local occupational therapy units on the incidence of finger deformities in rheumatoid arthritic population (Wong, 1990).

The aims of the study was to find out the incidence of the finger deformities in the local RA population and to study the correlation between different finger deformities.

Standard proformas were distributed among the six occupational therapy units. Therapists who were involved in the treatment of rheumatoid arthritic patients randomly select those patients under their care on the distribution of hand deformities and filled in the proformas accordingly. (appendix II)

A random sample of 60 subjects were reviewed by occupational therapists. Result showed that there is a relatively high incidence of flexion contractures or boutonniere deformities of PIP joints at the four fingers compared to other deformities (Table 3.1).

These results support the rationale for further studying flexion deformity in the proximal interphalangeal joints.

Finger affected	Number of subject	Percentage
Index finger	11	18.3 %
Middle finger	9	15 %
Ring finger	17	28.3 %
Little finger	14	23.3 %
Total	51	85%

Table 3.1 **The distribution of flexion contracture in RA hand(Wong, 1990)**

The most recent study conducted by Wong(1990) reflects the high incidence of flexion contracture at the PIP joint level. As mentioned in a previous review, the PIP joint is the epicentre and key joint of the finger digit. This study is therefore developed to analyse the therapeutic intervention regarding this problem. It is also important to have an indepth understanding on the aetiology of the flexion contracture.

3.3 Flexion contracture at the Proximal Interphalangeal(PIP) Joint

3.3.1 Causes of flexion contracture at PIP joint

Active synovitis of the proximal interphalangeal joint in the early acute stage will produce a swollen joint, particularly in the morning. Chronic oedema and immobilisation of the joint in a flexed attitude will result in flexion contracture of the joint. The following diagram illustrates how joint oedema limits finger extension at PIP joint due to the limitation of skin motion.

The disease can advance to the proliferative stage at which pain and finger joint swelling are now associated with stiffness due to the synovitis at the dorsal synovial space causing limitation in full extension. Fibrosis of the joint capsule will occur if there is chronic swelling at the joint.

As a result of chronic inflammation, shortening of the volar plate, with its proximal lateral check-rein extensiors and of the collateral ligaments may develop, causing the flexion deformity at the PIP joint. Tendon adhesions at the palmar skin, flexor tendons or sheaths may be associated components of flexion contracture. The following diagram illustrates the anatomical structure of the volar plate with the proximal lateral check rein liagment attached. Shortening will no doubt affect the extension of the joint.

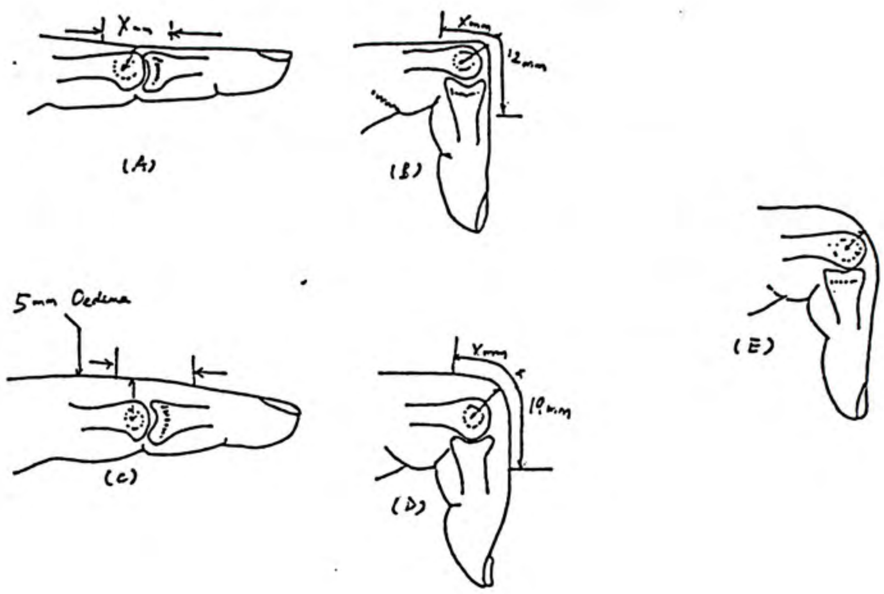


Fig 3.5 a) and b) Dorsal skin requires 12mm of lengthening for 90 degrees of flexion. c) and d) with 5mm of thickness of oedema, the skin requires 19 mm of lengthening for 90 degrees of flexion. e) with continuing torque, oedema fluid moves around, permitting the skin to cross closer to the joint axis. (Brand, 1985)

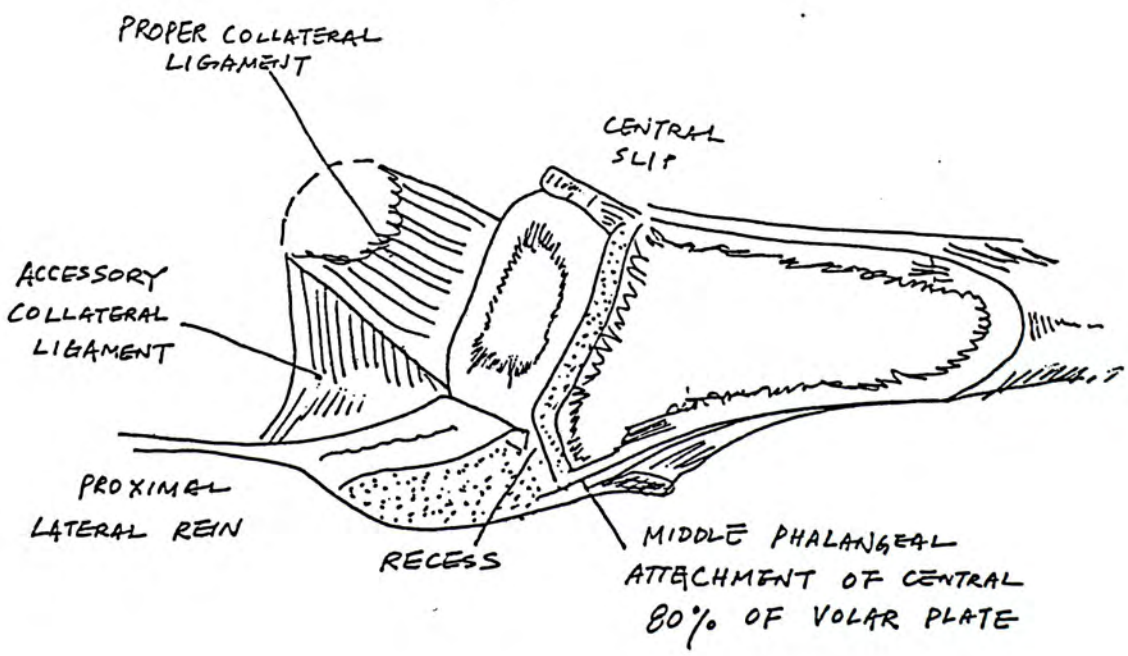


Fig. 3.6 Hemi section of volar plate. (Bowers, 1987)

Synovitis spreads proximally under the central extensor slip, which becomes attenuated, as well as between the extensor and intrinsic tendons. When the lateral bands migrate volarly, a boutonniere deformity is produced. With erosion of the joint surface, the middle phalanx may subluxate volarly. Collateral ligament adherence and contracture of the lateral band as well as retinacular ligament will produce a fixed deformity. In the final stage, fibrous or bony ankylosis of the middle joint can occur. Metacarpophalangeal joint hyperextension or failure to flex the joint fully develops as a compensatory mechanism to extend the finger that is held flexed at the proximal interphalangeal joint.

3.3.2 Implications for research

This study focuses on early intervention to correct the flexion contracture of the PIP joint before further joint destruction takes place. The investigator is well aware of the difficulties to control the inflammatory disease of RA. However, it is very important to bring to the attention of all therapists, patients and the rehabilitation team that one single joint may affect the hand functions. Any forms of therapy to remediate the limitation of motion due to flexion contracture is deemed necessary before the joint is fibrotic and bony ankylosis occur.

Chapter Four

Splinting for the Rheumatoid Hand

4.1 Splinting the Rheumatoid Arthritic Hand

4.1.1 Functions of splints in management of rheumatoid arthritis

Occupational therapists in the rehabilitation of rheumatoid arthritic patients are often challenged with progressive hand problems of pain, weakness, joint stiffness, decreased range of motion and deformities which may lead to functional disabilities. Splints are often prescribed to control inflammation, deformities and to aid in maintaining function of the rheumatoid hand(Gault et al(1969), Kennedy(1974), Carr(1978), Feinberg & Brandt (1981), Hanten (1982). However, different authors have different opinions on the effect of splinting to help solving the hand problems of rheumatoid arthritic patients but very few have their studies documented.

Hanten (1982) has conducted an extensive literature review on splinting for the rheumatoid hand. In her review, she identifies three major functions of splinting for rheumatoid arthritic patients in pain relief, correcting deformities and improving hand functions. Immobilisation splints are found to be effective in relief of pain and inflammation in the acute stage of disease(Flatt(1963) & Rotstein (1965). The effect of splinting to prevent or correct dynamic deformities are not well substantiated by research. Therapists are very concerned about the stretching effects of the splints in causing further joint destructions in the rheumatoid hand. Curits (1989) describes the importance of elastic splints as a form of conservative treatment of joint stiffness, contracture and deformity in rheumatoid arthritis. This study is therefore developed to investigate prospectively the effects of corrective splintage on finger flexion contracture and its effect on hand functions.

4.1.2 Effect of splinting in relief of pain and inflammation

Joint immobilisation through the use of handsplints has been advocated by many physicians when joints are inflamed. Dr. Rotstein(1965), Flatt (1963) and Shalet(1969) have identified the values of splints for decreasing inflammation, reducing stress to the joints and thus improving mobility and function.

In a survey done in 1981 by Judy Feinberg, Kenneth D. Brandt revealed that in the acute phase, resting hand splints are indicated to protect and rest the inflamed joints and at the same time maintain the joints in correct positioning.

Hand splinting for the purpose of pain relief and decreasing inflammation is thus concluded to be effective in the early stage of the disease.

However, many therapists are concerned on the effect of immobilisation which may result in decreased range of motion, decreased muscle strength and atrophy. Gault and Spyker(1969) concluded from the study that three weeks of immobilisation is beneficial for the affected joints for patients with low to moderate levels of joints involvement. However, there is a decrease of active range of motion and grip strengths after immobilisation initially.

In this research study, the investigator will explore whether static splints with a fixed period of immobilisation will decrease grip strengths and active range of motion.

4.1.3 Effect of splint on improvement of joint stiffness, contracture or deformities

Curtis (1983) comments that elastic splints and traction should be used early in the course of disease and continuously; the amount of tension should not produce swelling. There are very few research studies focusing on the effects of corrective splintage on joint stiffness or deformity. Bennet and Czap (1966) comments that faulty positioning due to pain and muscle spasm may lead to deformities. This faulty position may also lead to overstretching or contractures of ligamentous tissue, intrinsic and extrinsic hand muscles. Therefore, through proper positioning by splinting on a counter pressure will induce the equilibrium of the hand musculature. This is extremely important in the subacute or chronic stage whereby most patients are not aware of the development of joint contracture. The question which arises is how much should the counter pressure be applied to the joint.

Okamoto (1984) states that splinting may delay or prevent the deformities especially during the subacute and chronic stage when the insidious nature of the disease in the development of hand deformities go unrecognised. The goal of splinting is to prevent, delay or eliminate the forces causing pain and deformity such as flexion contracture of the PIP joints and swan neck deformities.

Most authors highlight the importance of corrective splintage in the management of flexion deformities to counteract the deforming forces. There are very few studies focusing on the actual measurements of amount of forces required for the correction, the duration of stretching or the corrective forces generated by the splint. All these factors vary among different splint designs and the effect of correction may therefore be different. If the forces are too high, the patient may feel pain at the stretched joint. And if it is too low, the corrective effect is insignificant. On the other hand, the corrective force generated by splints may produce other forces that affect the joint functions (joint compression forces and other joint forces).

It has also been highlighted by Strickland (1986) that prolonged gentle stretch is more effective than intermittent strong stretch to correct soft tissue contracture. However, if the joint is immobilised too long for stretching, the risk of decreasing range of motion and grip strengths may be higher. In order to compare the effect, these modalities have to be measured. No previous study has reviewed these factors before to allow one to conclude that splint intervention is effective for the rheumatoid patients.

4.1.4 Effect of splint on hand functions

Quest and Cordery in 1971 have developed a functional splint designed to prevent ulnar deviation on active flexion or under external pressure. The splint was applied to eight subjects and the results were favourable. But the study only reflects a small sample group. Moreover, there is no previous study on the effect of hand functions during or after the application of the splints.

Convery, Conaty and Nickel (1967) have studied 51 patients who were fitted with a functional splint. This splint was designed according to the principles of Bennet. It allowed motion only in functional planes. This dorsal splint had an action wrist, action metacarpophalangeal joint, with MCP extension assists, which could be adapted to correct the ulnar drift. The results showed that function was reduced when patients wore the splint. Progressive deformtiy was not consistently prevented by wearing the splint. There were more range of motion limitations in the splinted patients than without splinting. The criticism towards the splint design was that it tried to solve multiple joint problems with one device. Patients disliked the bulkiness of the splints. The authors did not conclude that splints could not benefit the rheumatoid hand but commented that the splint design has to be improved. This reminds researchers when developing similar studies that they should focus on single joint problem and reduce the complexity of the splint design. In this study, the investigator therefore focused on the Proximal Interphalangeal (PIP) joint flexion contracture to evaluate how the splint programme affects the hand functions of clients.

4.1.5 Principles in the design of splints for rheumatoid hand

From the above studies, it is important to understand the needs of the rheumatoid arthritic patients before prescribing any splints for them. The splint should be able to counteract the contracture developed at the joint level. It must also assist or enable the patient to participate and continue in activities that represent the attainment or maintenance of his highest functional level.

There are several guiding principles in the design of splints (Okamoto, 1984). The first step is to maintain the normal architecture of the hand. The amount of corrective force and the duration of wear should be measured and standardised. A simple design is welcomed by most patients especially for the ease of application and removal. Cosmetic appearance and ease of application also serve as a motivating factor for the chronic patients to comply with the wearing regime. Light, durable materials that are compatible with daily activities are recommended. If possible, the splinting programme should comply with the exercise programme of clients to increase and maintain joint mobility, muscle strength, endurance and improve circulation over the joints.

4.1.6 Conclusion

It is so difficult to simply compare the effect of a splint on rheumatoid arthritic patients simply without developing a treatment protocol. The extensive involvements of the disease and the complexity of some splint designs often hamper the patients' compliance in a splint programme. It is deemed necessary to understand the aetiology of the deformity, the amount of corrective force needed to counteract the deformity, how the force is distributed in the splint design and the wearing regime before a research design is established.

4.2 Splinting flexion contractures at the Proximal Interphalangeal Joints (PIP jts)

4.2.1 Splinting acting on fingers

In splinting the fingers, the anatomic, kinesiologic, and mechanical variables should be taken into consideration. These splints must adhere to the principles of design, fit, construction, and mobilisation. The major functions of finger splints is the correction or prevention of deformity, the protection of injured or repaired structures and the allowance of controlled active motion to specific joints. Finger splinting may also be used to decrease pain, enhance grasp and release patterns and provide stability to lax joints.

4.2.2 A Review of splinting designs for PIP flexion contractures

Splinting has been an effective modality in the reduction of PIP joint flexion contracture. The splints are generally divided into two groups, dynamic splints and static splints. Dynamic splints usually have a mobile component allowing movement of one or more particular joints. The beauty of dynamic splints is that they allow regular joint movements and at the same time provide the necessary support. Static splints have no movable parts and should hold the involved hand in an immobilised position. The common splint designs for flexion contracture of the PIP joints are:

A. Dynamic Splints:

a. Dynamic PIP extension splint (Fess, Gettle & Strickland, 1981)

It is a high profile dynamic splint designed with an outrigger attached to the base of the hand for providing a steady springy force to pull the PIP joint into extension. One disadvantage of this splint is that it will also pull the MP joint into hyperextension. Patient also found the splint very bulky and difficult to apply. For rheumatoid arthritic patients, this splint further interferes their hand function. Swanson(1985) adapted this splint design into his post operative management on flexible implant arthroplasty of MP joints of RA patients by using the outrigger to prevent and counteract the ulna deviation of the MP joints.

b. The Reversed Finger Knuckle Bender(Bunnell & Howard 1950, Boyles 1970)

It is a high profile finger splint which uses the rubber band force to extend the PIP joints. This is also a three point pressure splint. Pressure from the pads often cause complaints from patients and fitting is difficult (Torkelson, 1987). The corrective force generated by the rubber band will provide two resultant forces, the vertical component to counteract the flexion contracture and the horizontal component causing joint compression over the affected PIP joint. This may further damage the articular surface of the joint during motion.

c. The Capener splint (Capener 1967, Wynn Parry 1973, Colditz 1983)

This dynamic splint is originally designed to correct finger flexion contractures by providing a springy traction force from the coil attached. Wynn Parry in 1973 described in detail the procedures of fabricating the spring coil to fit individual clients. It also serves the purpose of strengthening the extensor muscles. Colditz (1983) highlighted the importance of a tailor-made splint for the individual finger and she exhorts the high patient tolerance and custom fit. She recommended this splint to be used for flexion contractures with 45 degrees or less. The splint can also be used as an exercising device to provide active assistive extension and to strengthen the flexor groups during flexion of the joint.

d. The LMB Wire-Foam splint (American Academy of Orthopaedic surgeons, 1985)

A commercial ready-made splint designed to allow active flexion and resisted extension of the finger. It is light weight and relatively less bulky. The idea follows the design of the capener coil splint but instead of the coil, the splint relies only on the springy property of two adajacent wires to counteract the resistive force. Therefore, it is less durable and less effective in providing a steady pull as compared to the capener splint. Moreover, it is difficult to fit individual finger as it is commercially fabricated in standard sizes. The amounts of force generated by the coil are grouped into three categories.

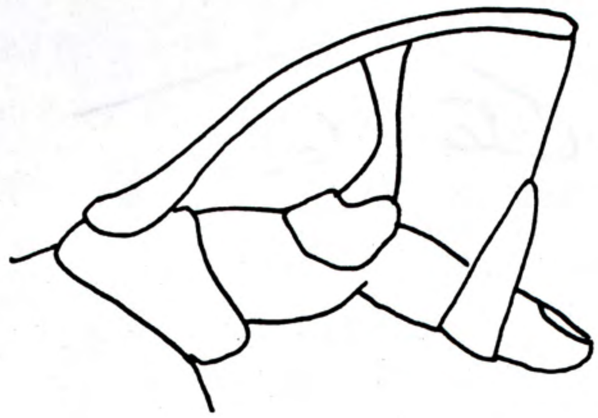
B. Static splints

e. The Safety Pin splint (Boyles, 1970)

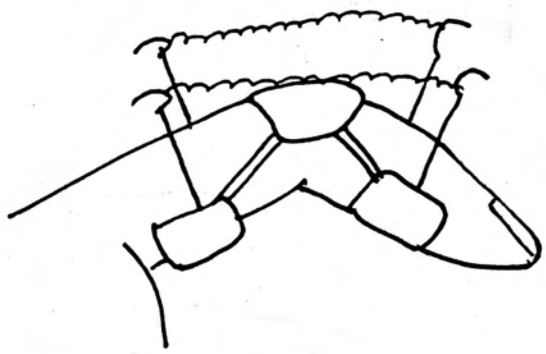
It is a commercially fabricated three point extension splint with two rigid longitudinal metal wires connecting the proximal, the middle and the distal trough. The pressure on the middle trough can be adjusted with a turn buckle. The chief complaint about this splint is the pressure placed over the PIP joint in order to counteract the flexion contracture. The contact area of the splint at the palmar side of fingers is also limited due to its rigid property. This would exert very high pressure on the small contact points.

f. The Joint Jack splint (Watson, 1982)

The splint resembles the safety pin splint. Torkelson(1987) described the splint as a turnbuckle, wedge type of splint which similarly has low tolerance by patients due to the pressure over the PIP joint and the counteracting two points at the palmar side.

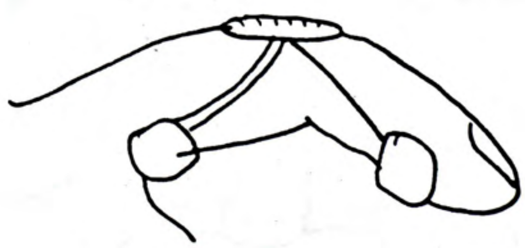


a. Dynamic PIP extension splints (Fess, Gettle & Strickland, 1981)



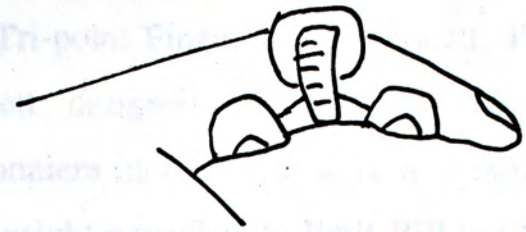
b. The Reversed Finger Knuckle Bender(Bunnell & Howard 1950, Boyles 1970)

c. The Capener splint (Capener 1967, Wynn Parry 1973, Colditz 1983)

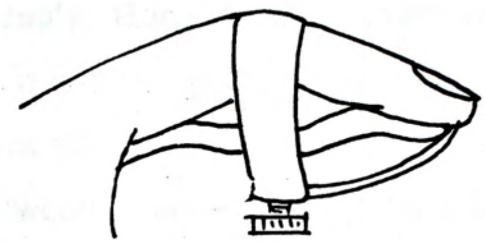


d. The LMB Wire Foam Splint

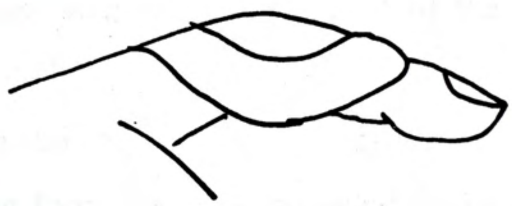
Fig. 4.1 **Diagram showing different dynamic finger extension splints**



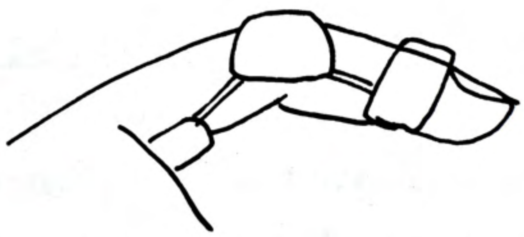
e. The Safety Pin splint (Boyles, 1970)



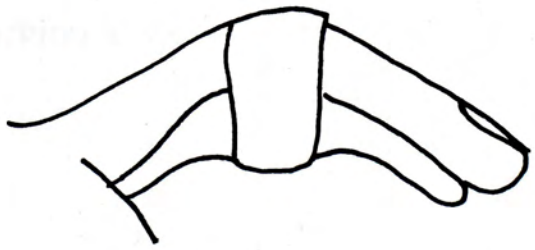
f. The Joint Jack Splint (Watson, 1982)



g. The Tri-point Finger Splint(Bennett, 1985)



h. The Spring Wire Splint (Callahan, 1987)



i. The Belly Gutter Splint (Wu, 1990)

Fig. 4.2 **Diagram showing different static finger extension splints**

g. The Tri-point Finger splint (Bennett, 1985)

Bennett designed a static tri-point finger splint for early boutonniere deformity. It is a 3-point splint fabricated from lightweight aquaplast to limit PIP joint flexion and is not bulky. It is extremely effective in the prevention of flexion contracture in the early stage of disease. Patients often find the splint handy and easy to apply. However, for flexion contractures more than 30 degrees, it is difficult to apply and remove the splint due to the narrow circumference at the PIP joint level. Moreover, the contact pressure would also be very high at the dorsal side of the joint.

h. The Spring Wire splint (Callahan, 1986)

It simulated the idea of the capaner splint but instead the coil is discarded with the replacement of the velcro loop to adjust the tension of the splint. It retains only the static part of the splint but the dynamic component has been removed. As a result, only static traction force could be provided to the patient. It is suitable only for patient with acute joint injury resulting in joint stiffness.

i. The Belly Gutter splint (Wu S.H., 1990)

Wu (1990) has modified the gutter splint into a belly gutter splint to correct the PIP joint flexion contractures. The splint provides traction tension at a 90 degrees angle to the phalanx by incorporates a convex belly in the middle of the gutter. He advocated that the splint can be used to correct flexion contractures at the PIP joint.

Wu (1990) used a simple mathematical model to analyse the mechanical properties of the static and the dynamic splints. The following diagram illustrates the simplified concept of force distributions on individual splint designs.

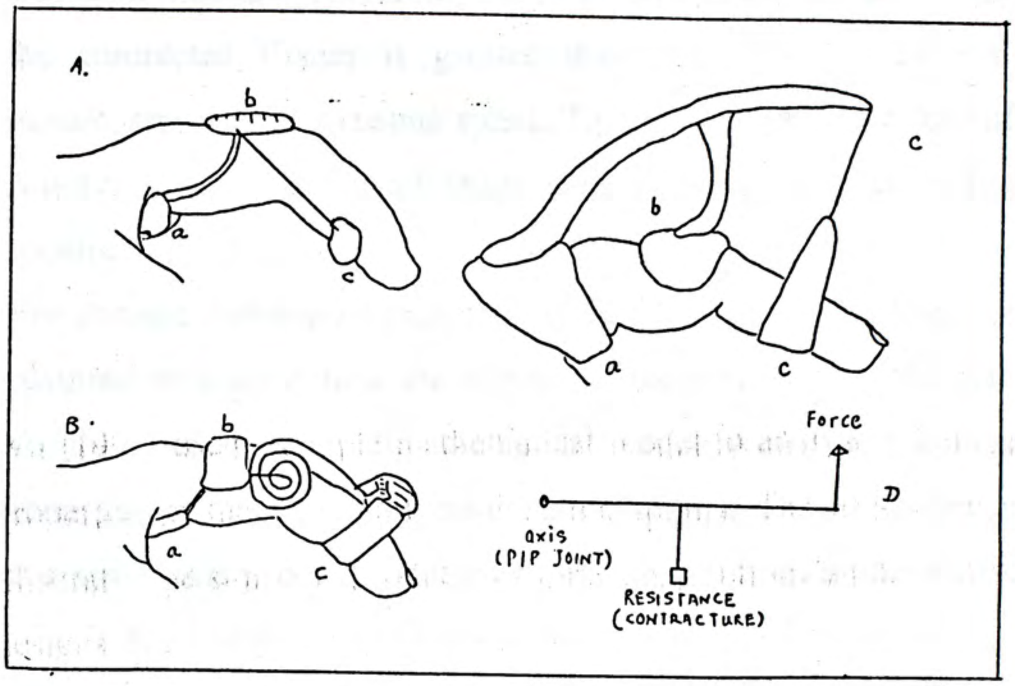


Fig 4.3 Diagram illustrating the line of forces for dynamic splints(Wu, 1990)

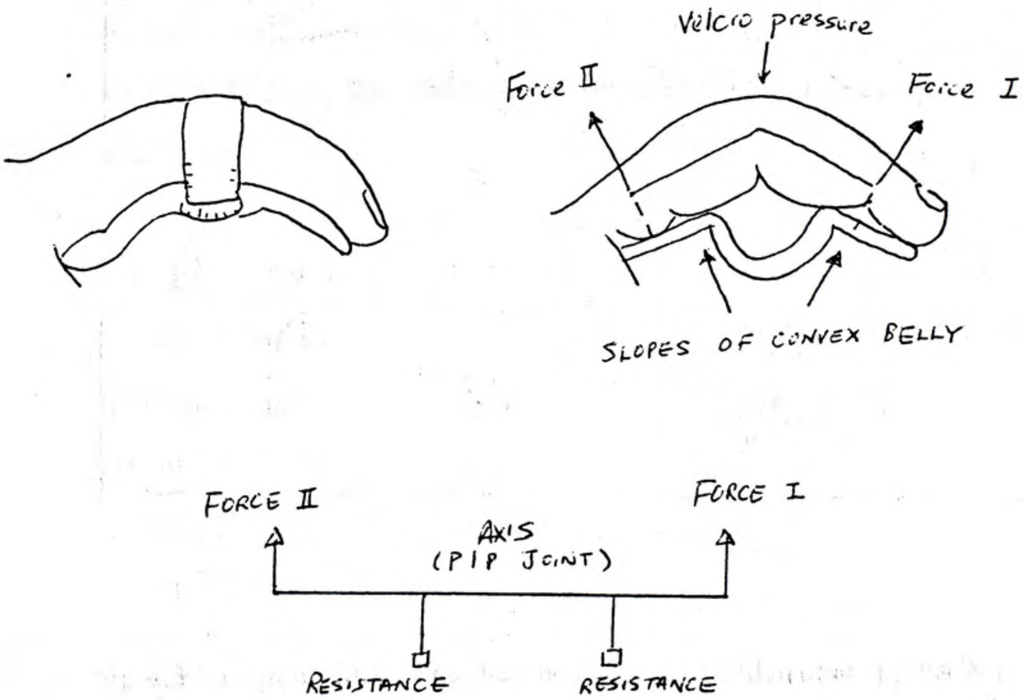


Fig 4.4 Diagram illustrating the line of forces for the static splints(Wu, 1990)

He concluded that both static splints provide second class levers, because the resistance (ie. the flexion contractures) is between the axis(fulcrum) and the force. He also pointed out that the static splints could provide two extension moments and the dynamic splints could only provide one extension moment. Therefore, the magnitude of the correction applied on the contracted tissues is greater than that provided by the elastic band/component of dynamic splint. This may be effective for stiff joints resulting from acute hand injury where greater corrective forces are required.

For chronic rheumatoid patients, detailed analysis of the joint forces are required to analyse how the corrective force will affect the joint. Care should be taken to monitor the splint wearing regime and the corrective force generated. One main concern is that most corrective forces will at the same time produce joint compression forces over the affected joint (fig. 4.8). The joint compression forces will greatly affect the already inflamed joint of RA patients. Also, if the period of immobilisation is too long, there may be a decrease of active range of motion and grip strengths (Gault & Spyker, 1969). If the corrective force is appropriate, it will create pain and discomfort.

In view of this, the mechanical properties of the two groups of splints are analsysed.

4.3 The mechanical analysis of splint design

4.3.1 Introduction

To follow up Wu's study in 1990, the investigator has conducted a more detailed mechanical analysis of the design of the static splints and dynamic splints.

4.3.2 The mechanical principles of static and dynamic PIP extension splints

Fess(1982) described some basic mechanical principles in splint design.

a. Therapist should consider the reduction of pressure by increasing the area of force application. In general, if the splint has a large contact area with the surface of skin, the pressure will be reduced. Both dynamic and static splints are constained by the length of each phalanx and the joint motion. The belly gutter splint is therefore better than the other three static splints because of increased contact area of force application. The other three dynamic splints are similar in contact area.

$$\text{Pressure} = \frac{\text{Total force}}{\text{Area of force application}}$$

b. The design and construction of splints should be adapted to include use of flavorable force systems. The ratio between the force arm and the resistance arm (MA) should be increased.

$$\text{Mechanical Advantage} = \frac{\text{Force Arm}}{\text{Resistance Arm}}$$

In the design of finger splint, the lever system is often restricted by the length of the finger digit. In this case, the belly gutter splint and the joint jack splint have a longer lever arm than the tripoint splint and the Callahan spring coil splint. The lever arm for the dynamic finger extension splint is longer than the other three dynamic splints (fig. 4.1).

c. Use optimum rotational force

The mobilization of stiffened joints through dynamic traction requires a thorough understanding of the resolution of forces to obtain optimum splint effectiveness without producing damage through joint compression or separation.

This explains why some three-point pressure splints such as safety pins splint, the Joint Jack Splint and even the Belly Gutter Splint become clinically less effective as the flexion angle of the joint is increased as shown in the diagram below.

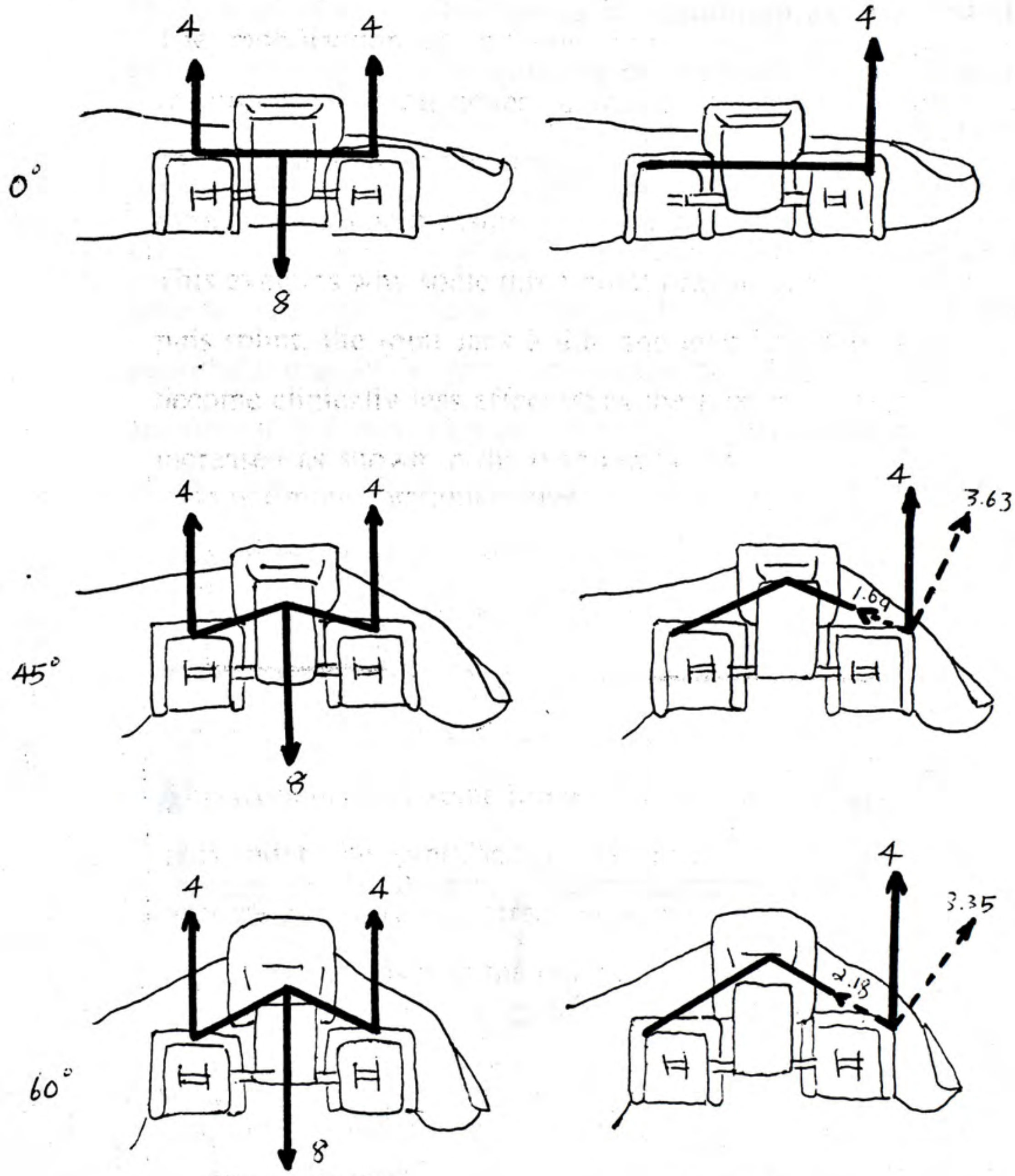


Fig 4.5 Diagram illustrating the distribution of resultant forces to counteract the flexion contracture at the PIP joint (Fess, 1982)

d. The torque effect of the splint should be considered.

Torque = Force x Force Arm

The amount of torque depends on the distance between the joint axis and the point of attachment of the dynamic assist. The torque increases as the distance between the two increases if the applied force is held constant. However, this is also limited due to the length of the digit.

e. Consider the effects of reciprocal parallel forces

The use of three parallel forces in equilibrum as in a first-class lever system is basic to splinting of the hand. In the first class lever system in equilibrum, the combined downward weights must be opposed by an equal upward force at the axis: A + B= C. The Belly Gutter splint and the Joint Jack splint has adopted this system. The middle force is frequently placed over the proximal interphalangeal(PIP) joint, care should be taken to minimise the amount of pressure exerted on the soft tissue especially if the synovitis starts at the dorsal part of the joint.

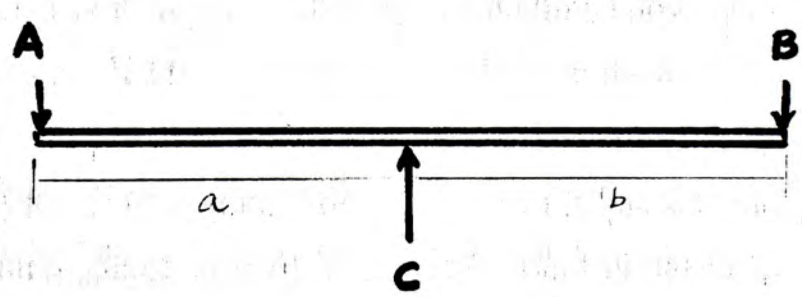


Fig. 4.6 Effect of reciprocal parallel forces
Force A + Force B = Force C

4.3.3 Summary

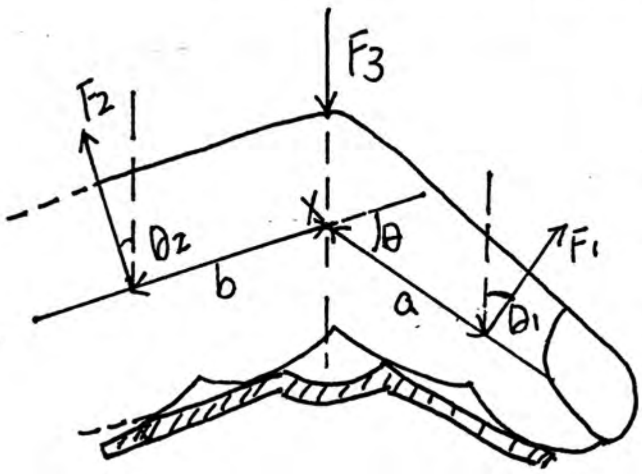
Among the four dynamic splints described, the amount of corrective force is adjustable except the LMB wire foam splint. The reverse knuckle bender splint and the dynamic finger extension splint are too bulky to be worn by RA patients. Only the capener splint fullfill most of the mechanical, cosmetic and general principles for RA patients.

For the static splints, the design of the belly gutter splint has provided a larger contact area of support. The pressure is reduced in general. For the safety pin splint and joint jack splin, the contact area vary according to the degree of flexion contracture(Fig. 4.5). The contact area is therefore greatest when the finger is fully extended. However, when there is flexion contracture, only a small contact point is created at both troughs. The splints are also bulky and difficult to apply. The tripoint is very handy but the pressure will be very high at the dorsum of the PIP joint when there is flexion contracture. The spring wire splint which is similar in design with the dynamic capener splint has similar property but with no adjustment of correction force.

4.3.4 Force analysis of the belly gutter splint and the capener splint

Based on some of the general and mechanical principles listed above, the belly gutter splint and the dynamic capener splint are selected for detail analysis of joint forces. The following diagram attempts to show the theoretical force distribution of the two splints.

a. Free body diagram of Belly Gutter Splint showing forces acting on finger



$F1$: corrective force acting on the finger at the distal part of the splint

$F2$: corrective force acting on the finger at the proximal part of the splint

$F3$: compression force acting on the finger by the velcro fastening

a : distance between PIP joint and the pt. of force application F1

b : distance between PIP joint and the pt. of force application F2

θ : Angle of flexion contracture

Force Equilibrum in the horizonal direction

$$F1 \sin\theta1 = F2 \sin\theta2$$

Force Equilibrum in the vertical direction

$$F3 = F1 \cos\theta1 + F2 \cos\theta2$$

(Assume $\theta1 = \theta2$, then $F1 = F2$)

$$F3 = 2\,F1 \cos\theta1$$

$$F1 = F3 / 2 \cos\theta1$$

$\theta = \theta1 + \theta2$

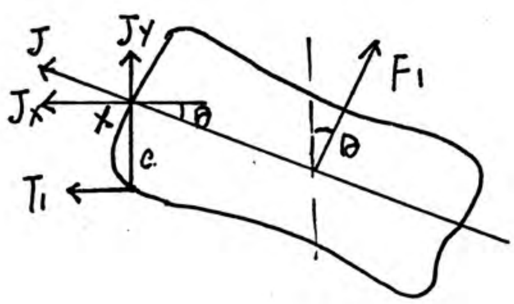
If $\theta1 = \theta2$

then $\theta1 = 1/2\,\theta$

Taking moment at X (centre of PIP joint)

$M_{corr.} = F1 . a = F2 . b = (F3.a) / 2 \cos\theta1 = (F3.a) / 2 \cos 1/2\theta$ since $\theta1 = 1/2\theta$

Fig. 4.7a Corrective moment at the finger generated by the Belly Gutter splint



J: Joint force acting onto PIP joint (Jx,Jy)

X : Centre of the PIP joint

F1: Force generated at the distal trough of splint

T1: Force generated at the joint due to contracture of soft tissue

a: Distance between centre of the joint to the corrective force

c: Vertical distance from centre of the joint to the palmar base of the joint

θ: Angle of flexion contracture

$Fx = 0 \Rightarrow Jx + F1 \sin\theta - T1 = 0$

$Fy = 0 \Rightarrow Jy + F1 \cos\theta = 0$

Taking moment at X, $T1 . c = F1 . a$

$T1 = F1 . a/c$

Therefore, $Jx = T1 - F1 \sin\theta$

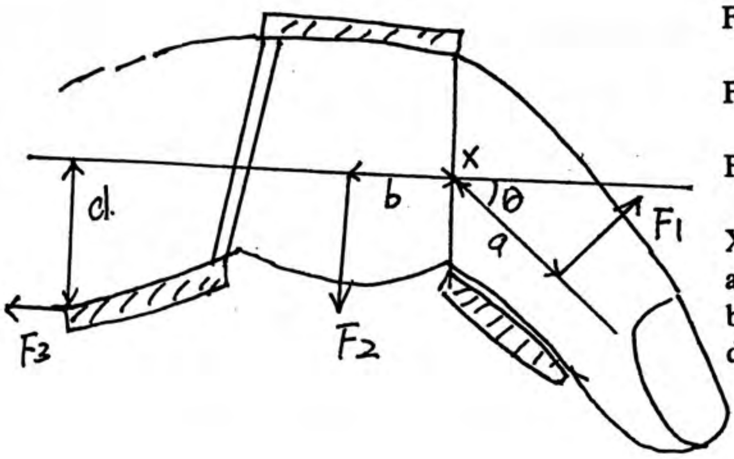
$= F1\,(a/c - \sin\theta)$

$= F3\,(a/c - \sin\theta) / 2 \cos\theta$

Assume F3 is constant, Jx will increase when θ increases (appendix XI)

Fig. 4.7b Splint Force acting on the PIP Joint by the Belly Gutter splint

b. Free body diagram showing the Capener Splint force acting on finger



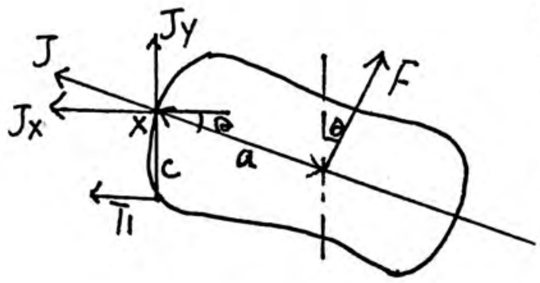
k :	Rotational Stiffness of the coil
θ :	Angle of flexion contracture
F1:	Force exerted by the distal trough to the finger
F2:	Force exerted by the middle trough to the finger
F3:	Force exerted by the proximal trough to the palm of hand
X :	Centre of the coil
a :	distance between X and F1
b :	distance between X and F2
d :	Vertical distance between centre line and F3

Force equilibrum at vertical direction => $F2 = F1 \cos\theta$
Force equilibrum at horizontal direction => $F3 = F1 \sin\theta$

Taking moment at Ø,
Mcorr. (corrective moment to counteract the flexion contracture)

$$
\begin{aligned}
k.\theta &= F1.a + F2.\,b - F3.d \\
&= F1.a + F1 \cos\theta.b - F1 \sin\theta.d \\
&= F1(a + b\cos\theta - d\sin\theta) \\
F1 &= k.\theta / (a + b\cos\theta - d\sin\theta)
\end{aligned}
$$

Fig. 4.8a Corrective moment at the finger generated by the Capener Splint



J:	Joint force acting onto PIP joint (Jx,Jy)
X :	Centre of the PIP joint
F1:	Force generated at the distal trough of splint
T1:	Force generated at the joint due to contracture of soft tissue
a:	Distance between centre of the joint to the corrective force
c:	Vertical distance from centre of the joint to the palmar base of the joint
θ:	Angle of flexion contracture

$$
\begin{aligned}
F_x = 0 &\Rightarrow J_x + F1\sin\theta - T1 = 0 \\
F_y = 0 &\Rightarrow J_y + F1\cos\theta = 0 \\
M_x = 0 &\Rightarrow T1.c = F1.a \\
&\Rightarrow T1 = (F1.a)/c
\end{aligned}
$$

Therefore,

$$
\begin{aligned}
J_x &= T1 - F1\sin\theta \\
&= (F1.a)/c - F1\sin\theta \\
&= F1(a/c - \sin\theta) \quad \text{(force compressing the PIP joint)} \\
&= k.\theta/(a + b\cos\theta - d\sin\theta)\,(a/c - \sin\theta) \\
J_y &= F1 \cos\theta \quad \text{(force acting downwards)}
\end{aligned}
$$

If θ increases, the joint compression force (Jx) will also increase (appendix XI)

Fig. 4.8b Splint Force acting on the PIP Joint by the Capener Splint

From the force diagram in fig. 4.5, Fess(1982) has deduced that the static splint is less effective in generating a corrective force when the flexion contracture is increased (in which the resultant corrective force is reduced). This can also be explained by the fact that if the flexion angle is increased, the moment arm of corrective force is shortened, thus the corrective moment will become smaller. The corrective moment generated by the capener splint is proportional to the angle of flexion contracture and the rotational stiffness of the spring coil(fig. 4.8). The amount of force applied can be monitored to fit the individual patient by adjusting the thickness of the spring wire and the circumference of the coil (appendix III). The corrective moment generated by the spring coil is stronger when the load is nearer to the coil. For the belly gutter splint, the corrective moment generated by the splint is directly proportional to the distance of application of force (a). If the moment arm (a) is longer, the resultant corrective moment will be larger. (MCorr.=moment arm x force)

The second deduction from the force diagram is that the joint compression force (Jx) created by both splints is proportional to the corrective moment generated by both splints. The stronger the corrective moment, the greater the joint compression force. This is a very important point to consider in adjusting the right amount of corrective forces to the joint. If the joint compression force is large, it may further damage the already inflammed joint.

The third deduction from the force diagram is that the greater the angle of flexion contracture, the joint compression force will be greater. This can be shown in the force diagram of the belly gutter splint in fig 4.7b in the last equation with the assumption that the corrective force (F3) remains constant. This also implies to the capener splint when the flexion angle is increase, the resultant joint compression force is higher. This is shown by the graph in appendix XI following the equation in fig. 4.8b.

Besides, the Belly Gutter Splint exerts the greatest corrective force (F3) at the dorsum of the PIP joint where the dorsal synovitis and oedema are present. This may create a lot of discomfort and pain over the joint. The capener splint spreads the load over the whole length of the dorsum of proximal phalanx instead of applying directly on the joint surface. Patient may find this more comfortable to wear.

Detailed analysis of the actual forces acting on the finger is described in appendix IV. The investigator attempted to use the Force Sensing Resistor (FSR) to find out the force generated onto the finger digit. It was shown that the force generated by the Capener Splint is loaded evenly to the three troughs at rest. For the Belly Gutter Splint, the force is maximal at the dorsum of the PIP joint underneath the velcro strap.

Moreover, the Belly Gutter Splint is to be worn over night where the PIP joint is constantly under the corrective pressure. The strap wrapped around the joint may be too tight and hinder circulation or too loose that it loses the corrective effect. On the contrary, the Capener Splint is to be worn during the day. The client can therefore observe the circulation of the finger when the splint is applied. The corrective force generated by the spring coil is carefully monitored by the size of coil, number of turns, thickness of the wire. The client can also gently exercise the PIP joint against the resistance of the spring coil. This will also maintain the mobility of the joint, muscle strength and improve circulation over the affected joint.

4.3.5 Conclusion

From the mechanical analysis and the laboratory study of the two types of splints, it was shown that the capener splint is more effective than the belly gutter splint in the correction of flexion contracture at the PIP joint. The static belly gutter splint causes more discomfort at the PIP joint due to the increased pressure at the PIP joint. The resultant joint compression force is also larger as compared to the capener splint. Therefore, patient may complain of more joint pain and discomfor. It is also less effective when the degrees of flexion contracture is bigger as the corrective force generated will be minimised (fig 4.4). The capener splint is more effective when the flexion angle is greater since the corrective moment is proportional to the angle of deflection and the joint compression force produced by the splint is less than the belly gutter splint when the moment arm is shorter. Yet, the investigator is also keen to explore how the splints affect the overall hand functions of the rheumatoid patients including active flexion of the joint, grip strengths, other hand functions and pain factor. What would be the better solution in correcting flexion contracture of the PIP joint needs further investigations. A clinical study is therefore planned to analyse on the effects of the these two splints.

Chapter Five
Hand Assessment in Rheumatoid Arthritis

5.1 Introduction

5.1.1 Rheumatoid arthritis is an unpredictable disease - no two patients have the same problems, and no one patient has the same problem for any great length of time except in chronic stages. Assessment should be carefully and objectively documented to truly reflect the necessity of, and the validity and effectiveness of treatment intervention (Slack, 1985). Objective measurement also provides a baseline for comparison which helps to quantify some of the therapist's impressions.

These include: Evaluation of range of motion,
Grip and pinch strength,
Objective hand function tests, and
Activities of daily living (ADL)

One of the aims of this study is to develop a comprehensive hand evaluation system for rheumatoid arthritis patients with multiple joint problems. Various hand assessment tools and assessment methods are reviewed and compared for their reliability and validity.

Active and passive range of motion should be recorded when possible, because this gives information about the location of the pathologic condition.

The traditional method of measuring grip strength by using a Jamar dynamometer. A grip strength of at least 20 pounds is necessary for most activities of daily living (McPhee, 1987). Below this level, patients begin to have difficulty in lifting objects and may require two hands to lift a coffee cup (Slack, 1985). Pulp, three-point, and lateral pinch are usually tested with a standard pinch meter. A pinch strength of 5 to 7 pounds is adequate for performing most daily tasks. A normal pinch strength is usually between 15 to 20 pounds. Pinch strength has particular application when assessing self-care skills, such as holding eating utensils, buttoning clothing, and writing (Slack, 1985).

Dexterity is tested by the use of standardised pick up tests or as a form of subtest in some hand function test. Changes in sensibility can also be noted with a simple pick up test. A more extensive hand function test, such as the Jebson-Taylor hand function test may be applied to those patients with more severe or complex problems.

It is important to consider that the severity of the deformity may not necessarily correlate with the patient's level of functioning. Often patients with very severe deformity function well. They have developed compensatory patterns that work well for them. Therefore, subjective evaluation of ADL functions is essential to document the progress of patient.

5.2 A review of the Standardised Hand Function Assessment

5.2.1 Descriptions of Hand Functions

Many investigators have characterized the hand's functional positions involved in manipulating objects. In 1942, McBride suggested functional descriptions according to the parts of the hand involved : grasping with the hand as a whole, grasping with the thumb & fingers, and combined use of palm and digits. Guffiths(1943) categorised the various hand prehension patterns as cylindrical grip, ball grip, ring grip, prices grip and pliers grip. Tylor and Schwartz (1955) expanded the classifications of hand functions by adding the terms grasp and prehension (lateral prehension, palmar prehension and tip prehension).

Napier drew attention to hand function by introducing the terms power grip, hook grip, precision grip and combination grip in 1956. Landsmeer (1962) discussed this point and suggested adding a dynamic perspective by changing the term precision grip to precision handling. Kapandji (1970) described a method of defining prehension patterns in terms of digital segments involved during manipulation. He used the terms palmar prehension, prehension by termino - lateral opposition and prehension between two sides of the fingers. Skerik, Weiss and Flatt suggested in 1971 that the terms power grip, lateral grip, hook grip, tip pinch, palmar pinch could adequately describe hand manipulation patterns.

More recently, Kamakuro, Matsuo, Ishir, Mitsushi, and Mirira (1980) conducted an extensive study on static hand prehension patterns in non-disabled objects. They were able to identify 14 basic patterns.

5.2.2 Assessments of hand functions

The main problem with these descriptions of hand function is that they are based on a generally static interpretation of object manipulation. They are descriptions of end product once the object is secured in position. The dynamic quality of hand function is glaringly absent.

Sollerman and Sperling (1976) developed a coding system to describe prehension patterns associated with object manipulation. This system uses code designations for variables associated with grasp patterns (five basic areas). This system addresses the dynamic relationship of motion in object handling and greatly enhances the accuracy of defining prehension patterns.

Sollerman and Sperling (1978) reported that all activities of the human hand can be divided into eight main types of hand prehension patterns including pulp pinch, lateral pinch, five finger pinch, preagonal volar grip, transverse volar grip, tripod, spherical volar grip and extension grip.

Bendz (1974) stated that the description of grip should include the various phases of the grip procedure in the initial opening phase, purposeful closing and stabilising phases, and the terminal opening phase. Static descriptions alone do not provide the information necessary for the hand therapist to determine the patient's grip pattern.

A hand function test should provide pertinent information about the performance of the hand as it accomplishes a task.

A competent hand function test should include a measurement of the quality of selected basic hand grasp patterns both dynamic and static; that is, it should provide a comprehensive assessment of the overall function of the hand as it accomplishes adequate object manipulation. Because a truly useful assessment determines how the hand functions in daily life situations, a hand function test should comprise tasks involved in activities of daily living and should use prehension patterns to the approximate extent that these patterns are used in daily life.

5.2.3 Functional hand assessment tests

A comparison of the published functional hand evaluation tests for rheumatoid arthritic patients is summarised by McPhee M.C. (1987) as follows:

Authors	No.of subtests	Functional tasks		Measurements		Sample Size	Reliability testing
		Unilat.	Bilat.	Obj.	Subj.		
Carroll (1965)	33	X	X		X	79	yes
Jebsen et al. (1969)	7	X		X		360	yes
MacBain (1970)	11	X	X	X	X	100	no
Clawson el al. (1971)	5	X	X	X		210	no
Potvin et al. (1972)	19		X	X		80	yes
Smith (1973)	13	X	X	X	X	91	no
Bell et al. (1972)	9	X	X	X		50	no
Walker et al. (1978)	5	X	X	X		145	no
Wilson (1984)	17	X	X		X	0	no
Mathiowetz, Volland et al. (1985)	1	X	X	X		628	yes
Mathiowetz, Weber, et al. (1985)	1	X	X	X		628	yes

Table 5.1 Summary of Functional Hand Evaluations Reviewed (McPhee, 1987)

Some characteristics of the functional hand evaluations are reviewed from the table. 91% of the tests use unilateral tasks whereas only 55% use bilateral activities. Five tests use unilateral activities exclusively, and one test uses bilateral activities exclusively. Only 27% of the tests use subjective grading systems. Carroll's (1965) and Wilson's (1984) tests use the subjective reporting system exclusively. In all, 82% of the tests provide objective measures. For the five tests, authors have reported on reliability testing.

Most (82%) tests use time score as the critical measure of function because of its application in statistical analysis. However, the limitation is the reaction time of the tester in starting and stopping the stop watch. Therefore, if the time count is a few seconds, error is high.

The described hand function tests are considerably varied and lack a clear consensus on a definition. The ability of a patient to use his or her hands effectively in everyday activities is dependent on mobility, muscle strength, sensation, co-ordination, and motivation. Hand function tests should use tasks representative of everyday functional activities.

Another criticism of these tests are lack of culturally relevant activities incorporated in the tests (e.g. uses of chopsticks). There is no local study on the standardisation of the test procedures and methodology. Therefore, no standardised test has yet been adapted to local Hong Kong situations. The local therapists found it so difficult to communicate among staffs and patients on the levels of functional disturbance for each individual. There is a pressing need to develop a local function test.

David Trench Rehabilitation Center in 1986 has started to develop the hand funcntion test for use in rheumatoid arthritic patients. One of the hand function tests, the Jebsen Hand Function test was selected and translated for assessing the functional performance of R.A. patients. Unfortunately, there is no documentation of the test performance among the rheumatoid population and normal subjects.

5.2.4 Jebson-Taylor Hand Function Test

The Jebson-Taylor Hand Function Test(Jebsen, Taylor, Trieschmann, Trotter & Howard, 1969) was originally developed to assess both prehension and manipulation skills with functional tasks. The test allows for the comparison of dominant and nondominant hands in terms of measurement of time taken to perform seven hand tasks. Normative data are available with divisions relative to age and sex.

There are seven subtests that assess the patient's ability to write, turn cards, manipulate small common objects, use a spoon, manipulate small disks, and achieve a wide grasp around both empty and full 1-pound cans. Written instructions are read to the patient. A stopwatch is needed for test administration.

One of the advantages of the test is that it can provide the examiner with measurable data regarding functional tasks. The test does not emphasize a need to document altered prehension and manipulation patterns, because the scores are based on completion time in seconds. The documentation on altered prehension is extremely valuable and is included in the observation section within the physical capacity evaluation. Its test and retest reliability was reported as ranging from r=0.67 to r=0.99 across the seven subtests(Jebsen, 1969).

The test is widely used as a standardised assessment for comparison of the effect of various wrist orthosis (Stern, 1991). Other researchers also adapted the test to their studies (Carlson & Trombly, 1983, Lynch & Bridle, 1989; Noronha, Bundy, & Groll, 1989; Kuphal, & Ramponi, 1988).

It is adopted as a diagnostic screening criteria in assessment the degree of disabilities on duchenne muscular dystrophic children (Hiller, 1992). Hackel (1992) also investigate the effect on aging on hand function as determined by the Jebsen Hand Function test. The results indicated that there are strong correlations between age and the time score for clients ranging 65 to 80 years old.

Stern(1992) in her study also reinforces Jebsen el al's (1969) report of strong test stability for five of the seven Jebsen-Taylor subtests. Only two subtests (writing and simulated feeding) demonstrated less stable results. These two subtests involved the use of hand tools and it was found that many subjects grasped the tools using different grip pattern. Therefore, the two subtests are considered to be the weaker elements within the hand assessment battery.

Therefore in this study, the Jebsen Hand Function test is adapted to test for the effect of corrective splintage on hand functions of rheumatoid hand. However, before the actual implementation of the test, it is important to standardise the test to normal and rheumatoid subjects in the Hong Kong settings. The results are discussed in Chapter six.

Fig 5.1 Diagram showing the Jebsen-Taylor Hand Function Test

5.3 Measurement of grip strengths

5.3.1 Introduction

The importance of documentation of treatment efficacy has become increasingly more important as therapists are more aware of treatment effectiveness. Successful delineation of treatment outcomes is dependent directly upon the use of instruments that can measure the functions both appropriately and accurately (Fess, 1992). Therefore, it is very important for researcher to choose suitable types of assessment tools in their studies. In measuring the grip strengths of rheumatoid patients, frustrations often arise when no recording was made available due to their weak strength. It was found that in a lot of local clinical settings, there are often variations in recording the grip strengths using different dynamometers. The thresholds of the dynamometers may be too high for the rheumatoid patients. A comparative study on the characteristics of each measurement device is thus essential so as to select the best assessment tool for RA patients.

5.3.2 The Jamar Dynamometer

Bechtol (1954) first introduced a grip dynamometer with hand adjustable hand spacings; known as the Jamar Dynamometer. It uses a sealed hydraulic system which registers force in pounds or kilograms.

Reynold and Toews(1970) conducted a very extensive study on measurements of grip strengths using the Jamar dynamometer. 1128 normal male and 80 normal female workers were tested with the Jamar dynamometer in a uniform manner using an alternating series of three trials on each hand. The authors commented that the dynamometer gave reliable and accurate readings when care is exercised in evaluation of the person to be tested.

Fess (1992) described four hand assessment instruments as the most reliable hand function measurement devices, one of which is the use of Jamar dynamometer in measurement of grip strengths. It was also commented that the dynamometer is only reliable with standardised calibrated methods and protocols.

Unfortunately, in the local clinics in Hong Kong, therapists are not familiar with the calibrated methods and protocols in employing the dynamometer. As a result, the outcomes of measurements may not be reliable. Experienced therapists commented that the dynamometer scores varied from one device to another.

It was also found that rheumatoid arthritic patients are found to be too weak to break the thresholds of the gauge. Often, zero reading is documented using the Jamar dynamometer. Most studies were conducted on normal subjects such as college students or steel workers(Kjerland 1953, Pierson & O'Connell 1962, Klimt 1969, Schmidt & Toews 1970, Kellor et al 1971, Nwuga 1975). Very few studies have been conducted on patients with hand injuries or arthritis.

Dent,J.A., Smith,M. & Caspers,J. conducted a study in 1985 to review some hand function tests. Jamar dynamometer was used to measure the grip strengths. The results indicated that the jamar dynamometer was quick to use, but five patients(three with RA) out of 25 subjects were unable to register any score. This indicated that the device may be ineffective to measure the grip strengths of rheumatoid arthritic patients.

5.3.3 The Linear force-summing hand dynamometer

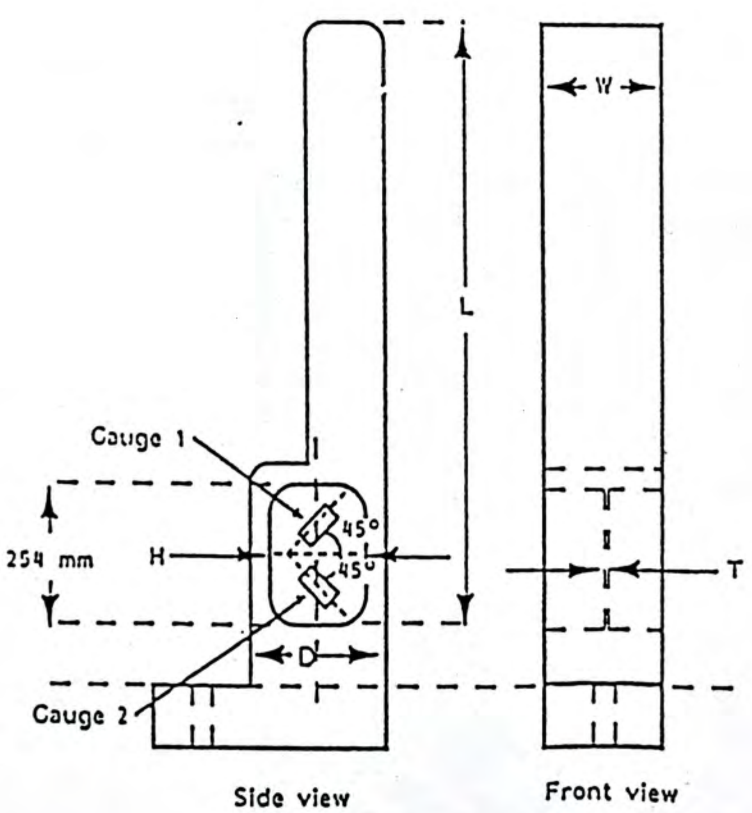
The linear force-summing hand dynamometer is developed from a strain gauge instrument that measures forces using the strain produced from the bending moment of a cantilever beam (Radwin, Masters and Lupton, 1991).

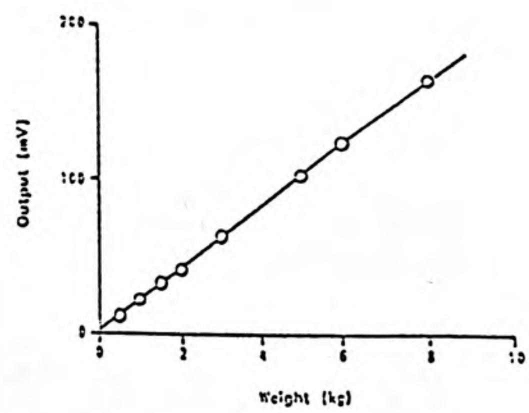
Pronk and Niwsing (1981) described a strain gauge dynamometer used for grip strength measurements that was independent of point of application of force. This instrument was based on the principle of measuring the shearing stress acting in the cross-section of a beam when a transverse force was applied. The dynamometer they developed was suitable for measuring grip at maximal contraction levels ranging between 5N to 500N for an accuracy better than 5%.

Since forces produced during power grip are applied equally and opposite against two bars in the direction of the resultant compressive force, the strain gauge dynamometer may be constructed using one active beam instrumented with strain gauges opposing a parallel reaction beam without strain gauges. This instrument may be used for comparing strength data obtained from a conventional spring grip dynamometer since force is measured in a single axis through the fingers and palm. In order to provide variable grip span, the beams were mounted on a track so that they were capable of being separated arbitrary distances.

The dynamometer was constructed for clinical applications to measure pinch force. It is documented that the device can measure very light forces (Radwin et al, 1991).

A similar design is developed in Jockey Club Rehabilitation Engineering Centre based on the grip strength dynamometer originally described by Pronk and Niwsing(1981) and Radwin, Masters and Lupton (1991). A computer software programme was also developed to document the maximum loading, the rate of grip and the grip vs time plot. The investigator would like to explore the sensitivity of the newly developed equipment as compared to the traditional use of dynamometers in the measurements of the grip strengths for our rheumatoid patients.





Dynamometer calibration curve

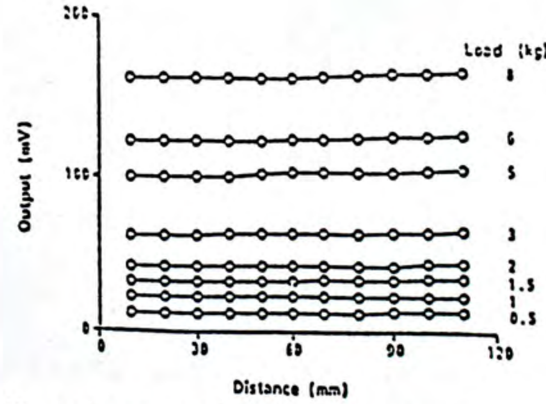


Fig 5.2 (Left) Schematic diagram containing dimensional variables for general dynamometer design

(Right) Graphical illustration of the output voltage plotted against distance along the length of the dynamometer(Radwin, 1991)

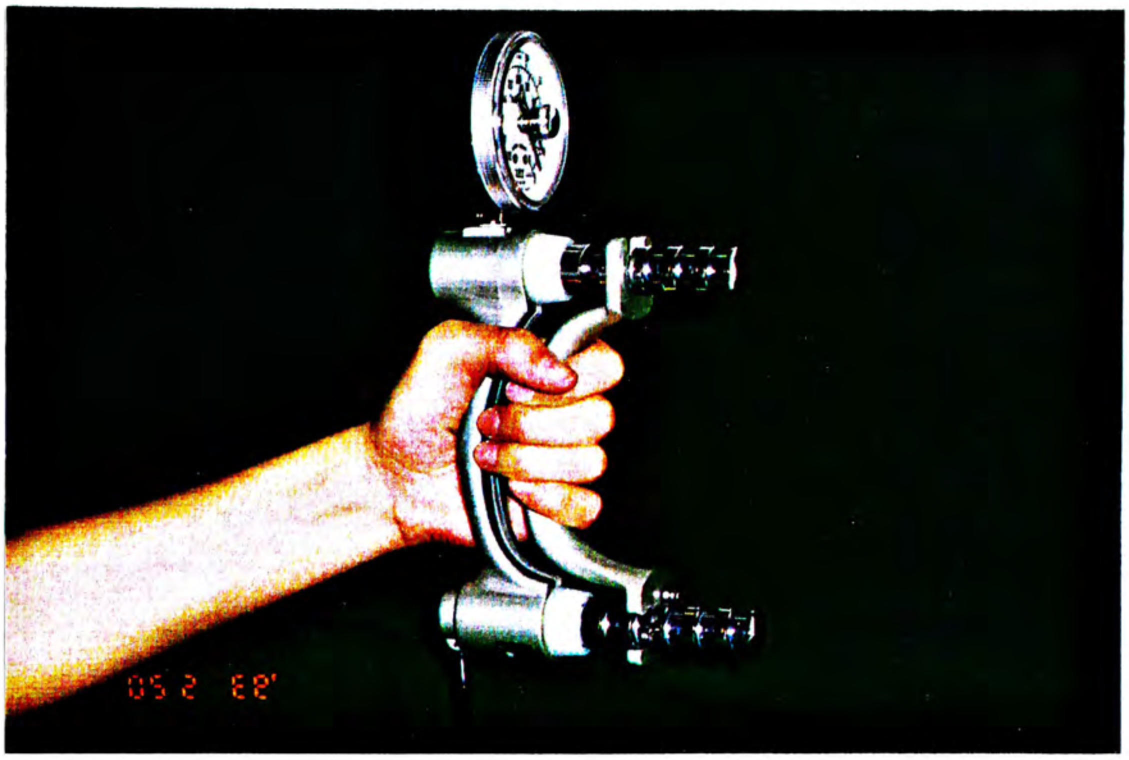


Fig. 5.3 Diagram showing the Jamar Dynamometer

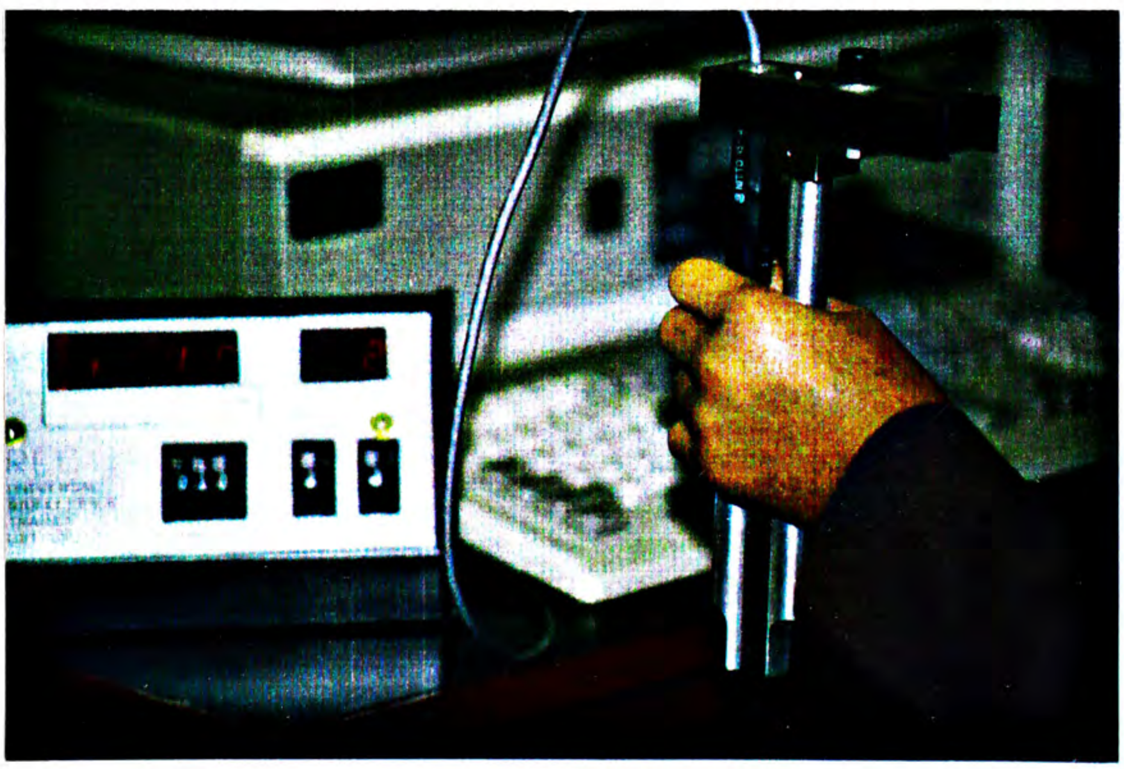


Fig.5.4 The REC prototype grip analyser

5.4 Measurement of active range of motion of finger joints

5.4.1 The finger goniometer

Trombly & Scott(1990) mentioned that the most widely used method of measuring joint motion is the system using the universal goniometer. The goniometer consists of a protractor, an axis, and two arms. The stationary arm extends from the protractor on which degrees are marked. The other arm is termed the movable arm and has a centre line or pointer to indicate the degrees of the angle measured. A finger goniometer is of a special design with a short movable arm and flat arm surfaces that fit comfortably over the finger joints. It was highlighted by Trombly & Scott that in order to have accurate measurement, the two arms must be placed in the plane of joint movement.

Cole (1971) and Boone (1978) reported that with careful adherence to technique in the use of the goniometer, measurements taken at different times by the same tester are accurate to within 3 to 5 degrees. Bonne (1978) also reported that those taken by different testers, using standard technique, are accurate to within 5 degrees for the upper extremity, and 6 degrees for the lower extremity. Bonne (1978) and Rothstein, Miller, Roettger(1983) also reported that interrater reliability from four therapists at four different test sessions are $r=0.86$ for upper extremity and $r=0.58$ for lower extremity. Intrarater reliability was $r=0.89$ for upper extremity and $r=0.80$ for lower extremity. Bonne (1978) did not conduct the study on the hand. There was actually little information in the literature to review the reliability of finger goniometer in measuring the joint motion of finger joints. The prediction is that the joints of the hand are small and is difficult to locate the exact joint axis. Only a little deviation from the joint axis would result in errors. Moreover, since the finger goniometer is small, the recorder may find difficulties to locate the exact readings from the protractor.

Fig. 5.5 The Finger Goniometer and the Electronic minigoniometer

Fig. 5.6 The Penny & Giles Electrogoniometer

5.4.2 Electronic minigoniometer

The electronic small joint goniometer is a new invention from Japan. It is small and handy with digital read out. The basic mechanism of the electronic minigoniometer is similar to the finger goniometer. It possesses two arms, an axis and a device to transfer the protractor reading to a digital reading.

The device is extremely handy to measure the proximal interphalangeal joint motion both in flexion, extension and hyperextension with a negative data. Most finger goniometers cannot measure both flexion and hyperextension in the same plane.

The digital goniometer is adopted in this study for measurement of finger joint motion because it can minimise human errors in reading the exact joint motion using digital display. However, it may not be able to solve application error in aligning the axis of the joint motion. This may be remedied by providing a consistent application procedure by one therapist.

5.4.3 Penny and Giles Electrogoniometer

The Penny and Giles twin axis goniometer permits the simultaneous measurement of flexion/extension and abduction/adduction of any joint(appendix V). Assuming the goniometer is mounted correctly as outlined below the output of the two channels is independent of linear displacements along axis ZZ. It should be noted that the rotation of one endblock relative to the other about axis ZZ cannot be measured. The goniometer assumes the motion to be in one plane. It may create a measurement error in cases where rotation of joint motion are present.

The G35 goniometer is a single axis goniometer intended for use on fingers and toes. The unit is designed to be fitted over the joint to be measured and has extremely high flexibility to ensure that the instrument does not interfere with the normal operation of the joint. The unit is only designed to measure flexion and extension.

Penny & Giles Goniometer can be applied onto a subject's finger and the range measured after calibration.

The sampling rate can be adjusted from 20-1000 per second or 20-1000 per minute. There are four channels in operation where a therapist can measure four different joints simultaneously during a functional task.

Each channel can be calibrated according to the full range of motion of a particular joint. The device is extremely sensitive in measuring torque motion of the joint by the strain gauge attached inside the goniometer. Recording is made possible via the data logger when the client carries out functional hand activities e.g. picking up a small object on table. This allows the investigator to understand the functional range of motion during the activities for different joints of the finger.

In this study, the investigator will compare the functional movements of a normal hand and a rheumatoid hand with flexion contracture at the PIP joints. This will allow the investigator to have deeper understanding of how the flexion contracture of the PIP joints will affect the hand functions. The findings would be discussed in chapter six.

Chapter Six

Development of Hand Evaluation System in Rheumatoid Arthritis

6.1 Introduction

In the comprehensive hand assessment of a rheumatoid arthritic patient, measurements of grip strengths, active range of motion, measurements of dexterity, pain factor and performance in activities of daily living are essential. As discussed in the previous chapter, there is at present no standardised procedures adopted in measurement of hand functions for our RA clients in Hong Kong. The reliability and validity of the Jamar Dynamometer and the goniometric measurements are doubtful in measuring grip strengths and range of motion. There is also no previous study on any standardised hand function tests ever investigated and conducted locally.

In the following study, the investigator has designed a series of laboratory tests and small scale studies to verify the validity and reliability of the assessment methods to be adopted in the main study.

6.2 Aims of study

One of the main aims of this research study is to develop an objective, comprehensive and standardised hand evaluation for rheumatoid arthritic patients. The purpose of developing this evaluation protocol is to provide an objective evaluation to measure the hand function of clients who suffer from the disease. The impairment of hand function varies among the client groups and subjective assessment by means of observation or patient interview may not be sufficient. The hand evaluation system if developed can be used to verify the effectiveness of treatment intervention.

6.3 Development of the Hand Evaluation System

The study is divided into three parts of research. Firstly, the REC prototype grip analyser and the Jamar dynamometer are chosen for a comparative study on its validity in measurement of grip strengths. Secondly, the Jebsen Hand Functions Test was selected for standardisation in local situations. Thirdly, the procedures of measurements of range of motions were analysed. An attempt has been made to analyse the functional range of motion during the performance of the seven subtests in Jebsen Function tests using the Penny and Giles Goniometer. The outcomes of the studies would form the framework of the hand evaluation system in RA patients.

6.4 A Comparative Study of Hand Grip Assessment Tools: The Jamar Dynamometer, the preston pinch gauge and the REC prototype grip analyser

6.4.1 Aims of study

The laboratory study aims at comparing the accuracy of two grip strength measurement tools : the Jamar Dynamometer, the preston pinch gauge and the REC prototype grip analyser in measurement of hand grip strengths of rheumatoid patients.

6.4.2 Methodology

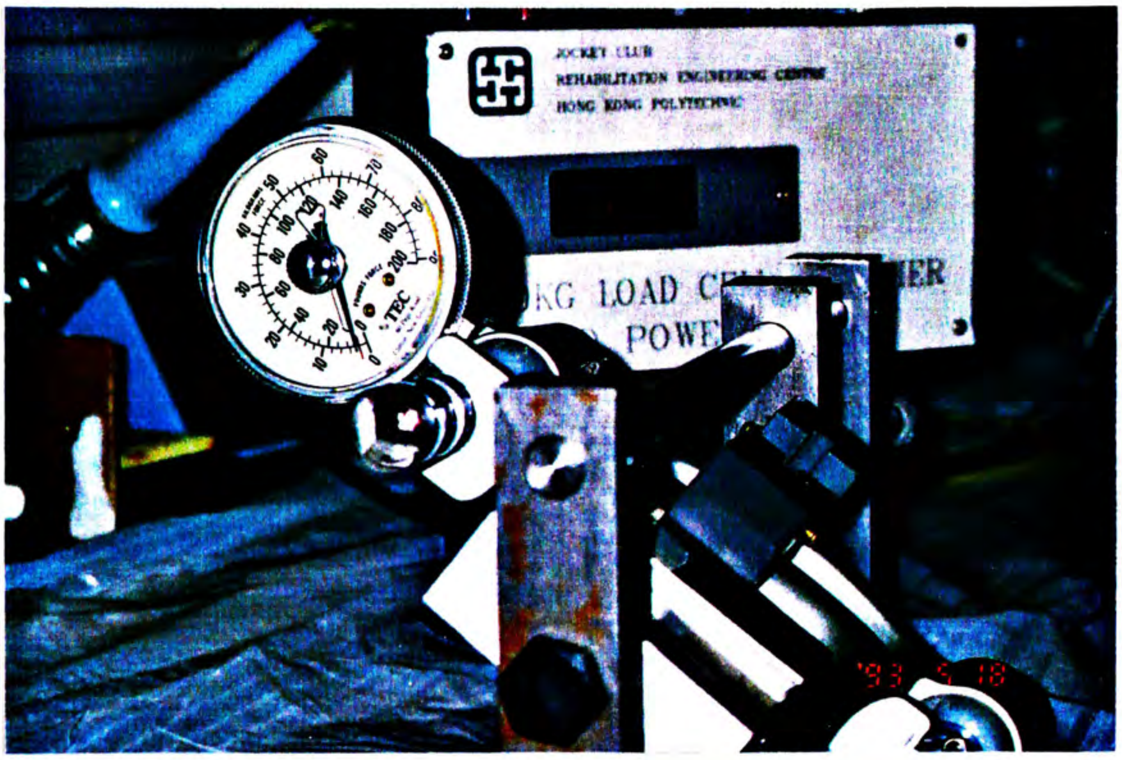
a. Six Jamar dynamometers of the same hydraulic system design and four preston pinch gauges were loaned from various occupational therapy units including Queen Elizabeth Hospital, Kwong Wah Hospital, Ruttonjee Hospital, Kowloon Hospital, Prince of Wales Hospital and Hong Kong Polytechnic for conduction of the comparative study.

The device is set up connecting the load cell device consisting of strain gauge and the Jamar Dynamometer in series as shown in the diagram below. The load cell is initially calibrated using the loading machine (a) in the diagram below.

The force is applied by tightening the screw at one end of the device at a right angle to the middle part of the shaft of the dynamometer and the load cell. The investigator first screws the device to the maximum load around 45-55 kg generated by both the dynamometer and the load cell. Then it is gradually reduced. The second step is to screw the device slowly at 1kg interval reading from the Jamar dynamometer. The load cell reading is then recorded twice. The average of the two readings are plotted against the actual load cell readings. In this way, the speed of the application of force would not interfere with the comparison. The point of application remains the same for all the dynamometers.

The readings obtained from Jamar Dynamometer and the load cell are taken at 1 kg intervals. All the six dynamometers are compared using the same load cell. The results of the study are charted for comparison.

b. Similar testing procedures are conducted for the four preston pinch gauges and the results illustrated with graphs.



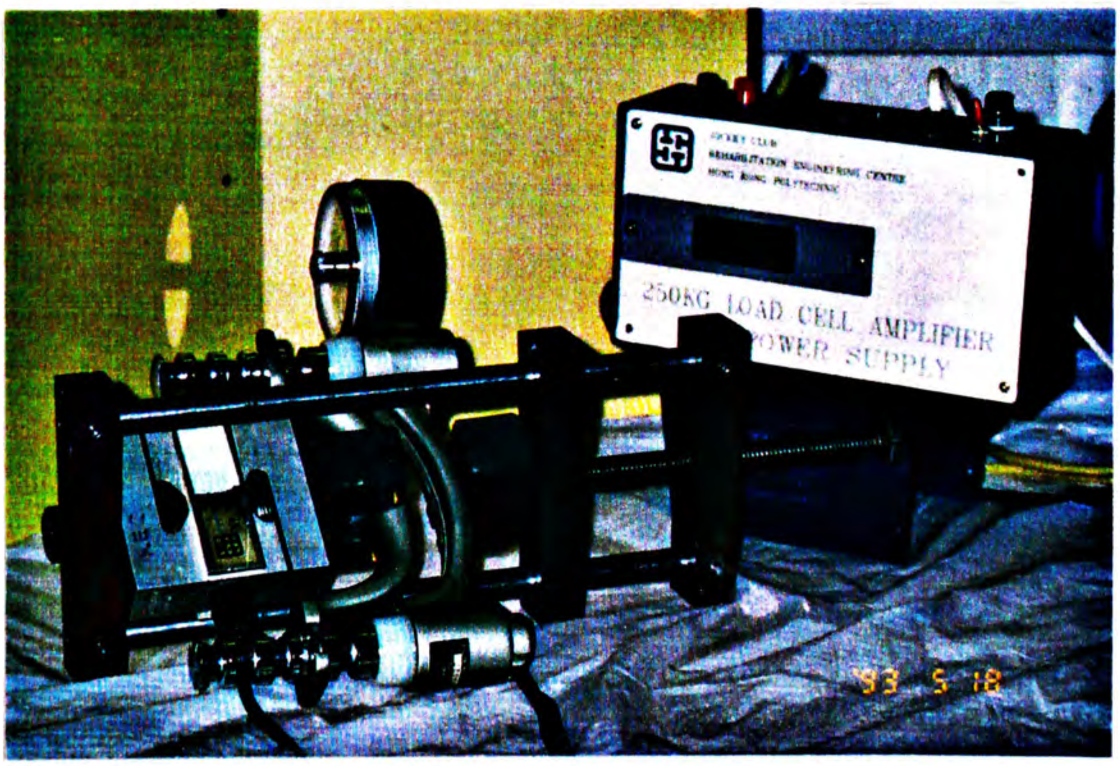


Fig. 6.1 The Jamar Dynamometer connecting to the load cell

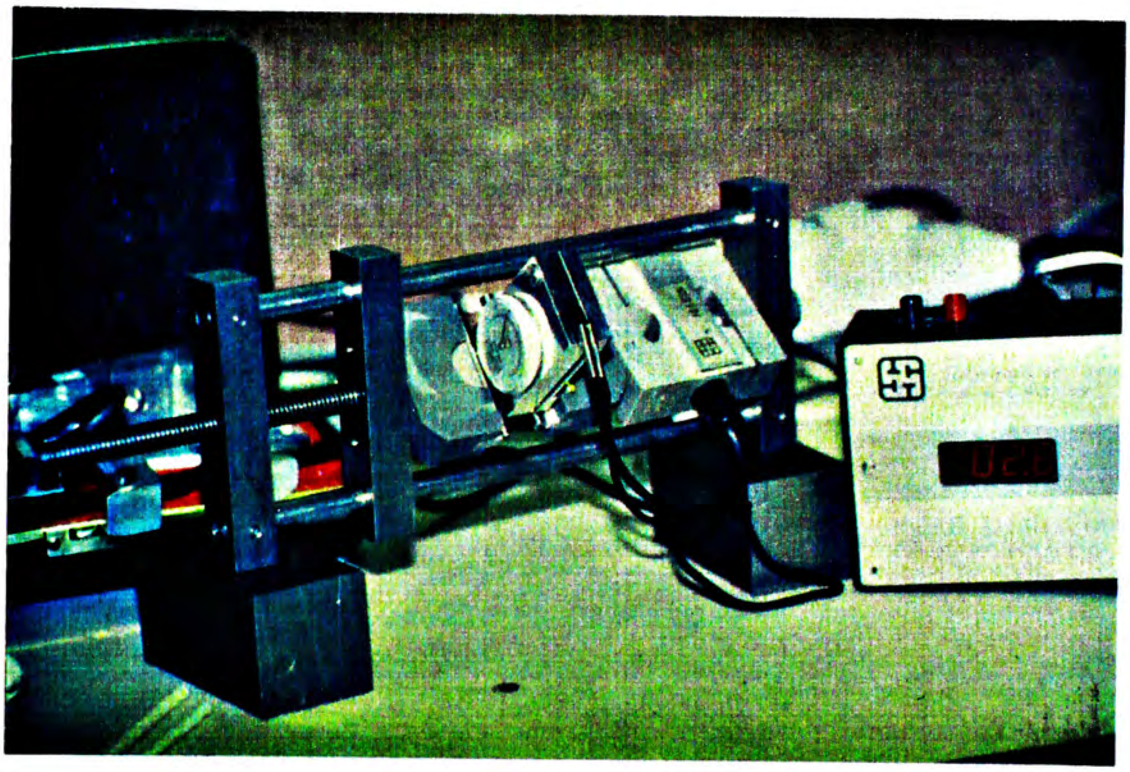


Fig. 6.2 **The preston pinch gauge connecting to the load cell**

6.4.3 Results

The Jamar Dynamometer vs the load cell

a. The initial threshold of each dynamometer varies from 0 to 4 kg.

b. The readings of each dynamometer is different from the readings of the load cell and that the deviation is not consistent (appendix IX). Four dynamometers show overshooting of readings in the initial range but undershooting of readings when the grip forces increase. The remaining dynamometer demonstrate a consistent undershooting of the actual values but the deviation is much higher when the grip force increases.

c. At the range of 0-10kg measurements, all five devices show a deviation between the range of 0-5 kg for the same load cell reading. When the grip mesurement increases, the deviation range is less (0-1kg). One dynamometer in particular demonstrated a consistent lowered readings than the actual reading. The deviation is higher when the grip measurements are higher.

d. The score measured from the dynamometers are in general higher than the actual reading from the load cell in the first 10kg of measurements except the dynamometer from Ruttonjee Hospital.

e. Starting from 10 kg onwards, the dynamometer readings have a higher correlation with the load cell readings except one dynamometer.

The Preston pinch gauge vs the load cell

a. At the range of 0-4kg of measurements, the three pinch gauges demonstrate a high correlation with the load cell reading within the range of 0.4 kg error. The pinch gauge from Queen Elizabeth Hospital has shown a great deviation from all other readings indicating that there might be a mechanical error of the device itself.

b. At the range between 4 to 10 kg, all four devices showed a wider range of deviation from the standard line. This indicates that the readings generated by the four pinch gauges are not comparable with the same amount of forces generated. The scores from the pinch gauges are in general higher than the score obtained from the load cell.

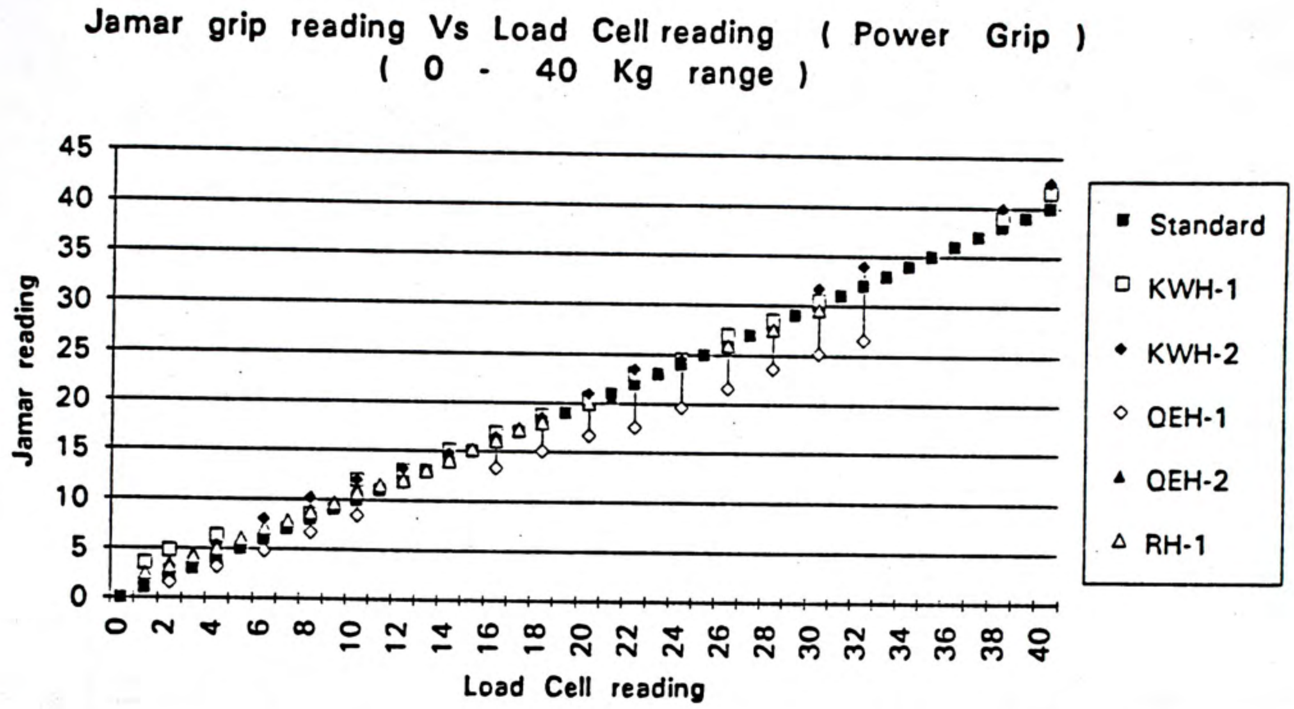


Fig. 6.3 The graphical illustration on Jamar measurements vs Load cell reading (0-40 Kg)

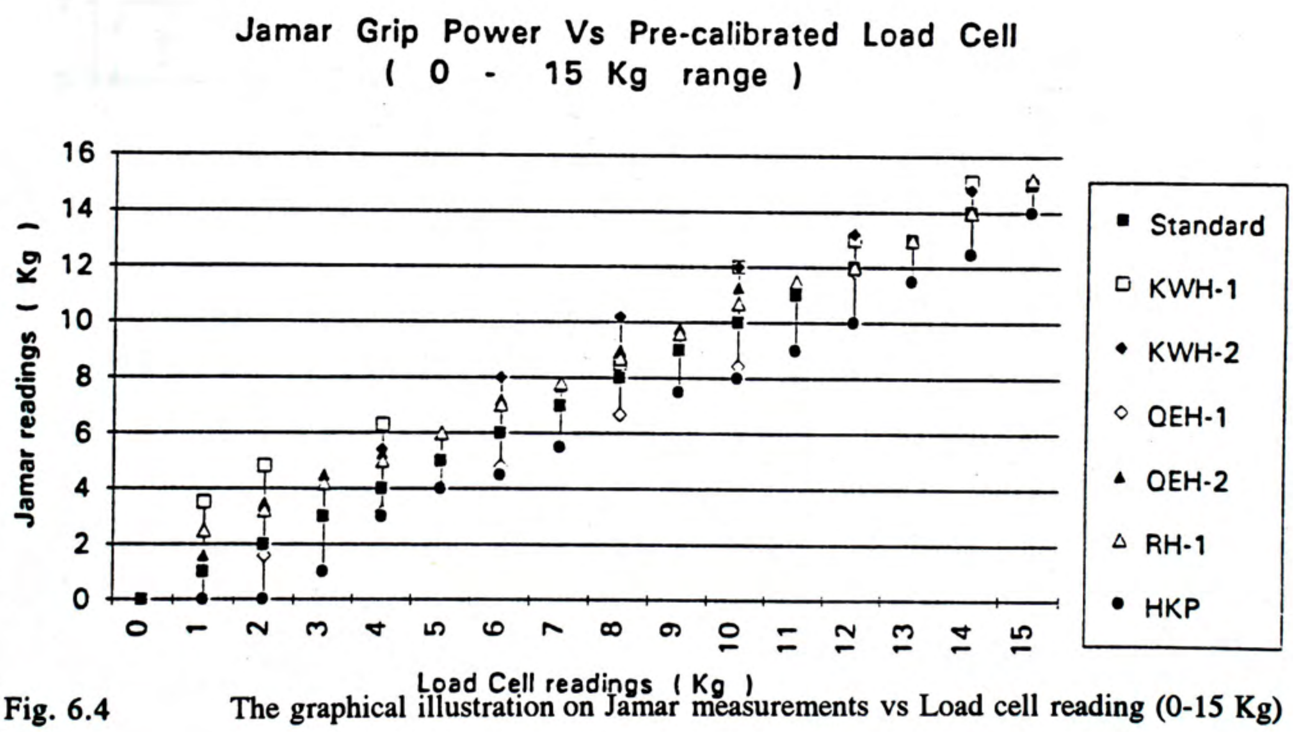


Fig. 6.4 The graphical illustration on Jamar measurements vs Load cell reading (0-15 Kg)

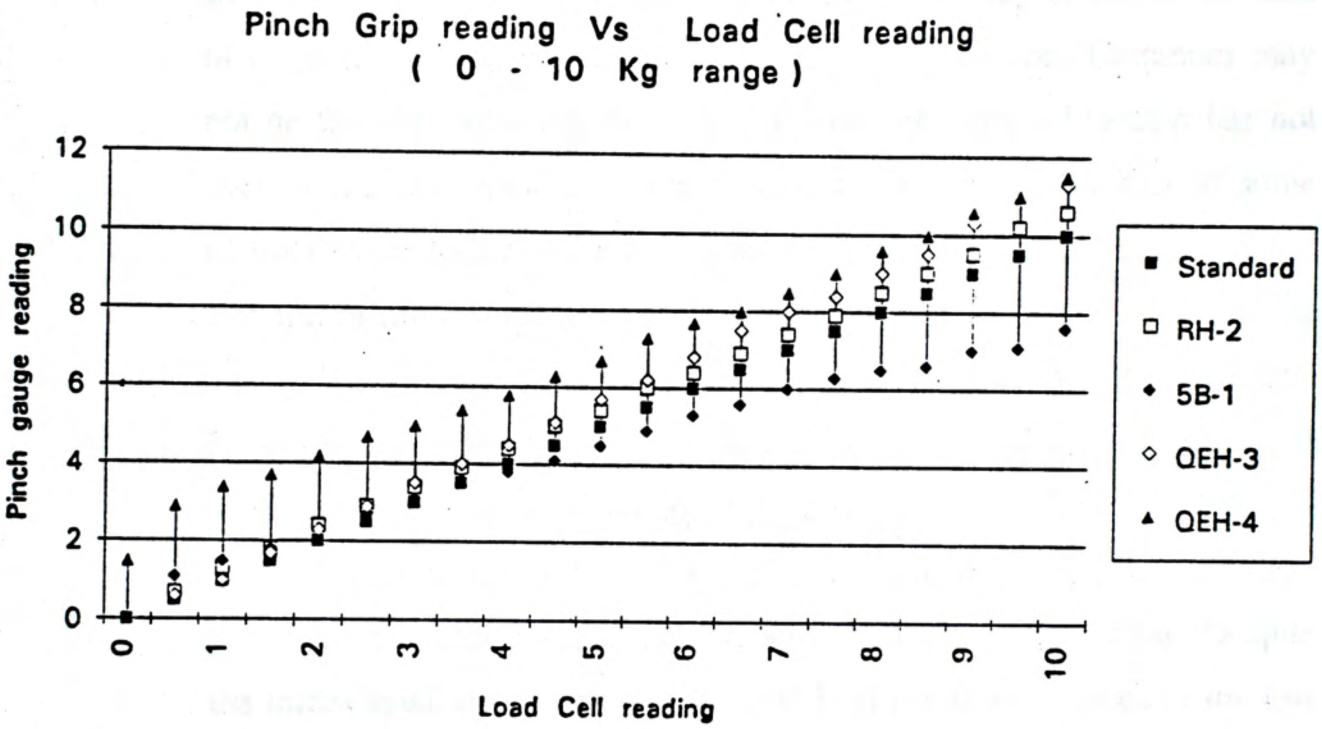


Fig. 6.5 The graphical illustration on Preston Pinch Gauge vs Load cell reading

6.4.4 Discussion

The results showed that the Jamar dynamometers did not give a true reading of grip strength especially when it is below 10 kg, and varied a lot between different dynanmometer. As the grip measurement increases above 10 kg, the readings from different dynamometers become more comparable. The error of mesurement at the lower end range is extremely high.

The deviation characteristics of each device is inconsistent. A few dynamometers still give resproducible results but it is not reliable to compare scores among different units and for objective recording.

The reason for such a wide variation of readings may be due to the lack of ongoing calibration procedures on individual device. Therapists may not be familiar with the calibration procedures, thus calibration has not been conducted. Another factor may be due to material fatigue as some of the dynamometers have been used for more than eight years.

For the preston pinch gauge, correlation between the devices and the load cell was quite high in the initial 0 - 4kg range of measurements. However, there was still a difference of 0.4kg for different devices. This indicate the difficulty of comparing scores among different units. The pinch gauges in general gave a higher reading than the load cell. The variations of each device from the actual reading is non-linear. Despite the initial small deviations (less than 0.3kg) for some devices in the low range, when the forces increased, the deviations enlarged obvious.

6.4.5 Limitation of the study

The number of dynamometers sampled for the study is too small to determine any generalised statement on the device. Further studies on the validity and reliability of the equipment is deemed essential. Although the load cell was calibrated in the similar procedure as the REC prototype grip analyser using the loading machine, it would be ideal to repeat the testing procedure connecting the grip analyser to the load cell for comparison.

6.4.6 Conclusion

From the above study, it is concluded that the Jamar Dynamometer cannot be used to measure accurately the grip strength of rheumatoid arthritic patients as they usually have weak grip less than 10kg. A more sensitive device, the REC prototype grip analyser is recommended for measuring clients with weak grip strength.

In this study, the investigator has adopted the use of the grip analyser in measuring the grip strength.

The preston pinch gauge is a sensitive device in measuring the pinch strengths of clients only if it is within the range of 4 kg. The error is higher when the pinching force is higher. The investigator has also adopted the use of the REC prototype grip analyser in measuring the pinch strengths of the subjects.

Both Jamar Dynamometer and preston pinch gauge demonstrated individual device characteristics and the scores of one device are different from the other device(appendix IX). However, the dynamometers can still be used for measurements of grip strength provided a calibration graph is produced to get the actual readings (appendix IX). Therapists have to be very careful in using the tools for assessment of grip strength. It is recommended that the therapist should use the same device for measuring the same patient in order to monitor the progress.

6.5 A comparative study on the Jebsen Hand Function Test in Hong Kong and USA

6.5.1 Introduction

Before the test is adopted to be used in our main study, there is a need to launch a preliminary study on whether there is a deviation of findings for the local population.

In 1990, a small scale study was conducted by the investigator assisted by four occupational therapy students on the development of the Jebsen Hand Function Test.

6.5.2 Aims of the study

(1) to standardise the procedures of the Jebsen Taylor Hand Function Test for local use;

(2) to compare the local score from the local population with the US score;

(3) to study the correlation of the test performance with the functional classification of RA patients

6.5.3 Methodology

(1) The instructions of the Jebsen Hand Function test was translated into Chinese and written into a manual(Appendix VI). The assessment tools were then developed according to the description(Jebsen, 1969) as illustrated in the diagram.

(2) 60 normal subjects were selected with the following criteria

  a. age between 15 to 60

  b. no hand impairment

  c. good comprehension, good eyesight

(3) The subjects were asked to perform the Jebsen Hand Function Test with clear instructions(see appendix VI). The tester followed strictly the instructions being translated into Cantonese.

(4) The time score for each subtest was then recorded separately on a standard form using a stop watch.

(5) The test was repeated on 30 patients with rheumatoid arthritis and their functional class were diagnosed by the case doctor.

6.5.4 Statistical analysis

(1) For the normal subject group, the mean scores of each subtest are compared to the US norms developed by Jebsen (1969).

(2) For the rheumatoid arthritis group, the total scores of the test are compared according to the functional levels of the clients. The Kruskal-Wallis 1-way ANOVA test is used to analyse if there is significant difference in the three groups.

6.5.5 Results

a. <u>The Normal Subject Group</u>

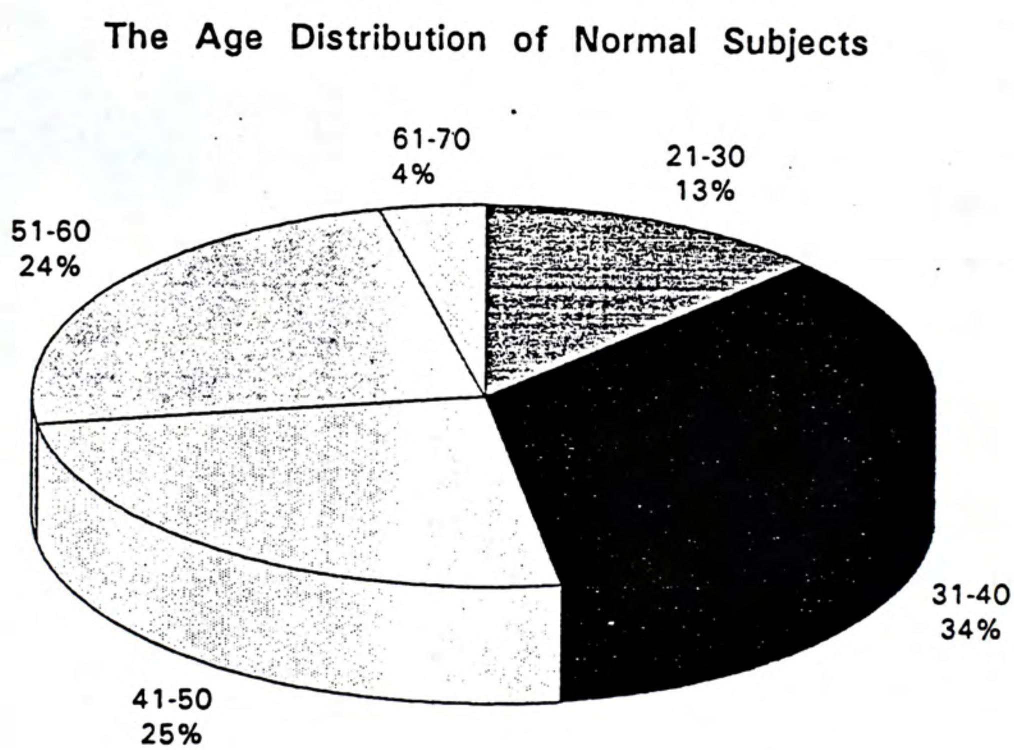


Fig. 6.6 Age distribution (normal subjects)

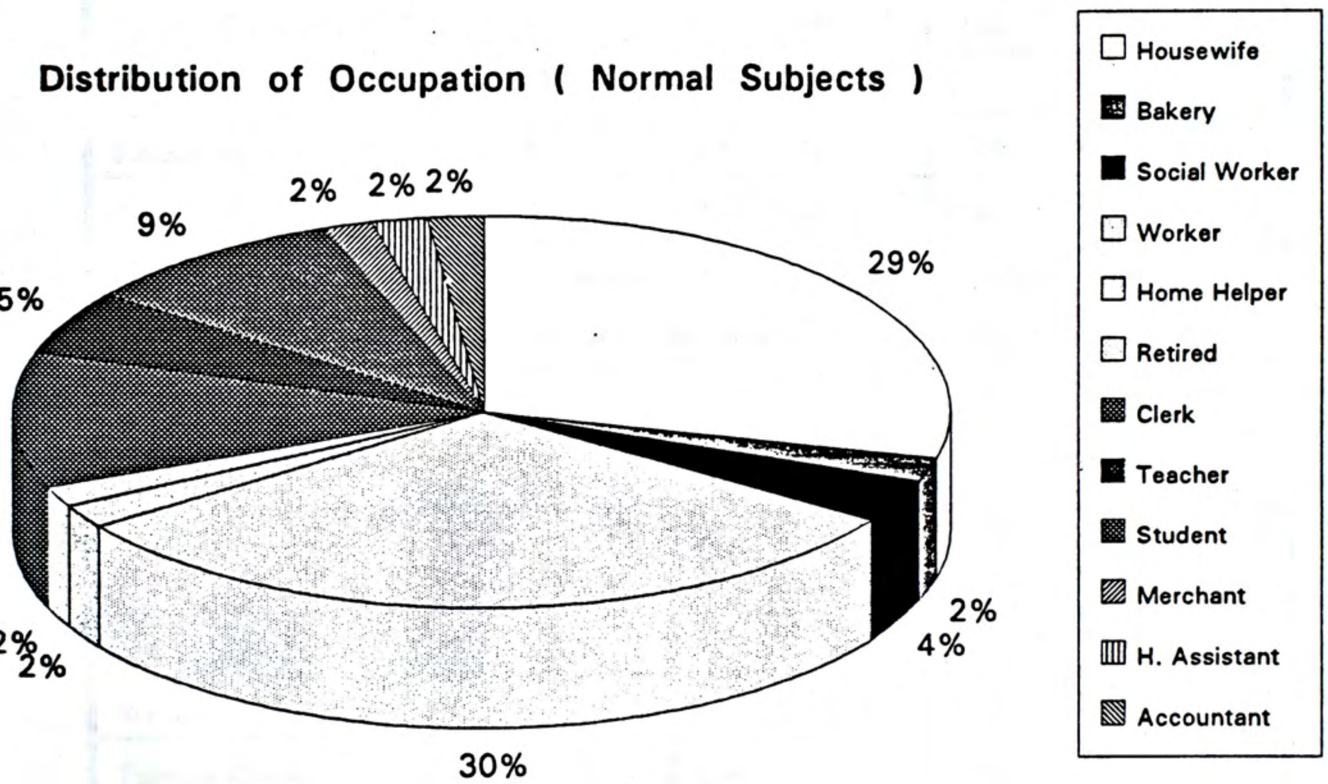


Fig. 6.7 Distribution of occupation (normal subjects)

The results of the local study showed that the mean times and standard deviation for normal subjects (both dominant hand and non-dominant hand) as compared to the US norms are quite similar.

Country	U.S.A. Mean(S.D.)	Hong Kong Mean(S.D)	Diff. Mean	% Diff.
No. of subjects	120	55		
Writing	11.7 (2.1)	11.98 (7.34)	0.12	1.02%
Turning Cards	4.3 (1.2)	4.8 (1.47)	0.5	11%
Picking Up Small Objects	5.5 (0.8)	6.18 (1.04)	0.58	12.3%
Simulated Feeding	6.7 (1.1)	7.34 (1.48)	0.64	9.5%
Stacking chess	3.3 (0.6)	3.3 (0.65)	0	0%
Picking up light cans	3.1 (0.5)	3.52 (0.9)	0.42	13.5%
Picking up heavy cans	3.2 (0.5)	3.68 (1.1)	0.48	15%

Table 6.1 Mean times scores for normal subjects (USA vs Hong Kong) (dominant hand)

Country	U.S.A. Mean(S.D.)	Hong Kong Mean(S.D)	Diff. Mean	% Diff.
No. of subjects	120	55		
Writing	30.2 (8.6)	31.45 (16.58)	1.25	4.1%
Turning Cards	4.8 (1.1)	5.44 (1.62)	0.64	13.3%
Picking Up Small Objects	6.0 (1.0)	6.94 (1.96)	0.94	15.6%
Simulated Feeding	8.0 (1.6)	9.18 (2.13)	1.18	15.6%
Stacking chess	3.8 (0.7)	3.9 (0.93)	0.1	2.6%
Picking up light cans	3.3 (0.6)	3.79 (0.8)	0.49	12.1%
Picking up heavy cans	3.3 (0.5)	3.96 (0.83)	0.66	20%

Table 6.2 Mean times scores for normal subjects (USA vs Hong Kong) (non-dominant hand)

The graph below illustrated the difference in mean score between the US data and the Hong Kong data.

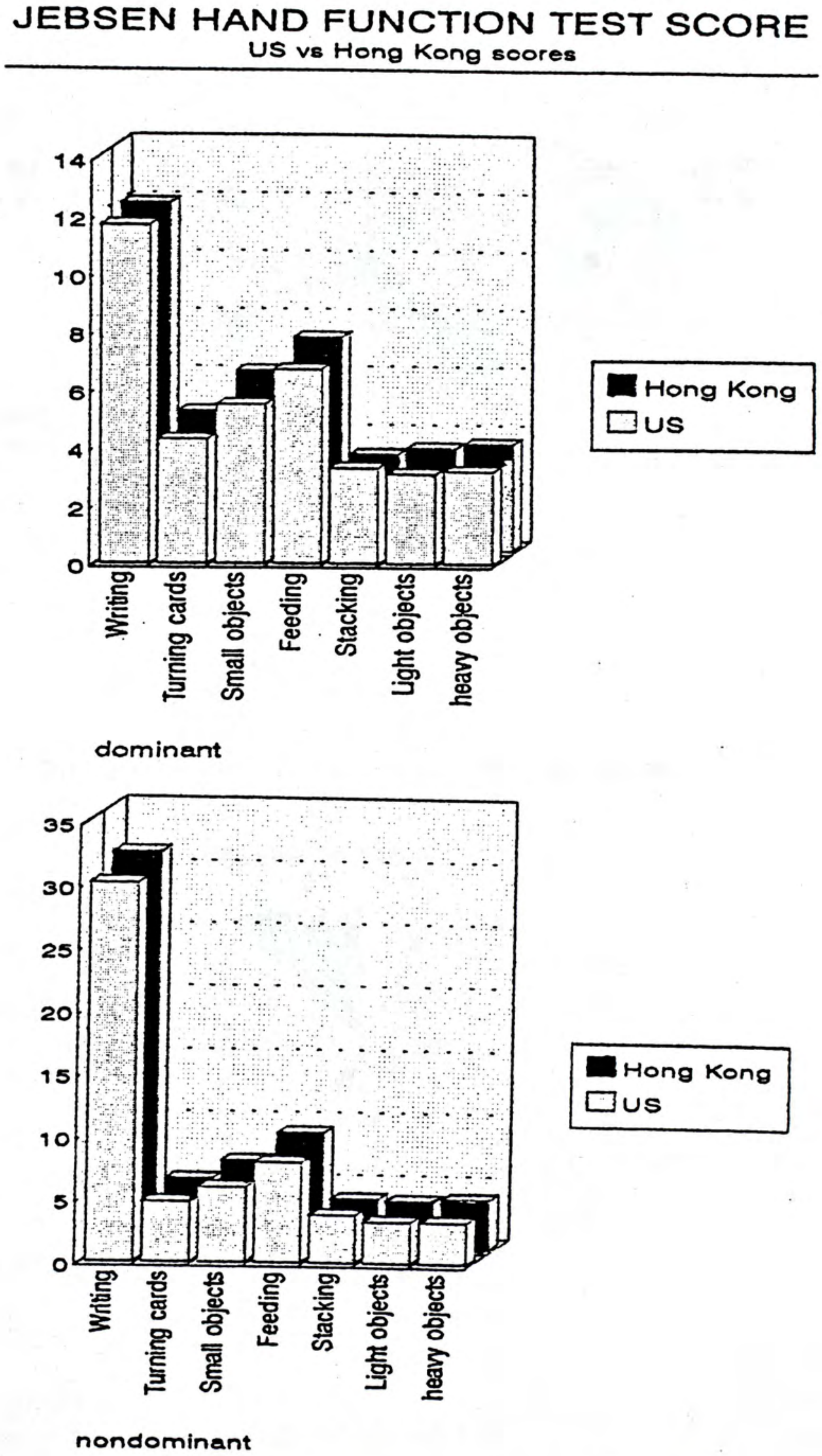


Fig. 6.8 Graphical illustration of the US and Hong Kong scores

b. The Rheumatoid Arthritis group

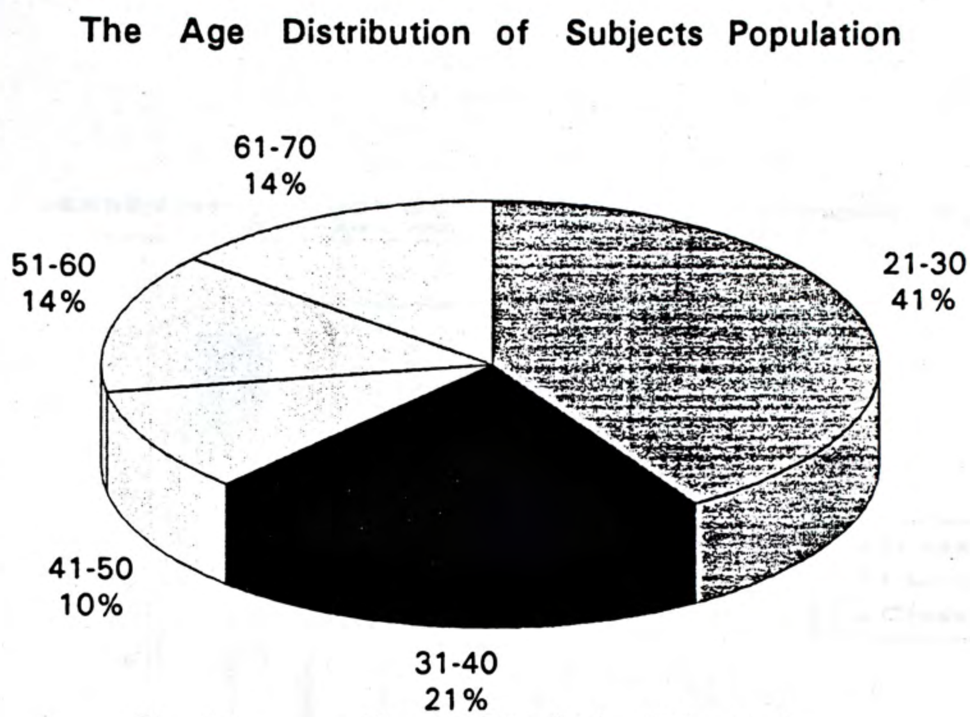


Fig. 6.9 The Age Distribution (RA group)

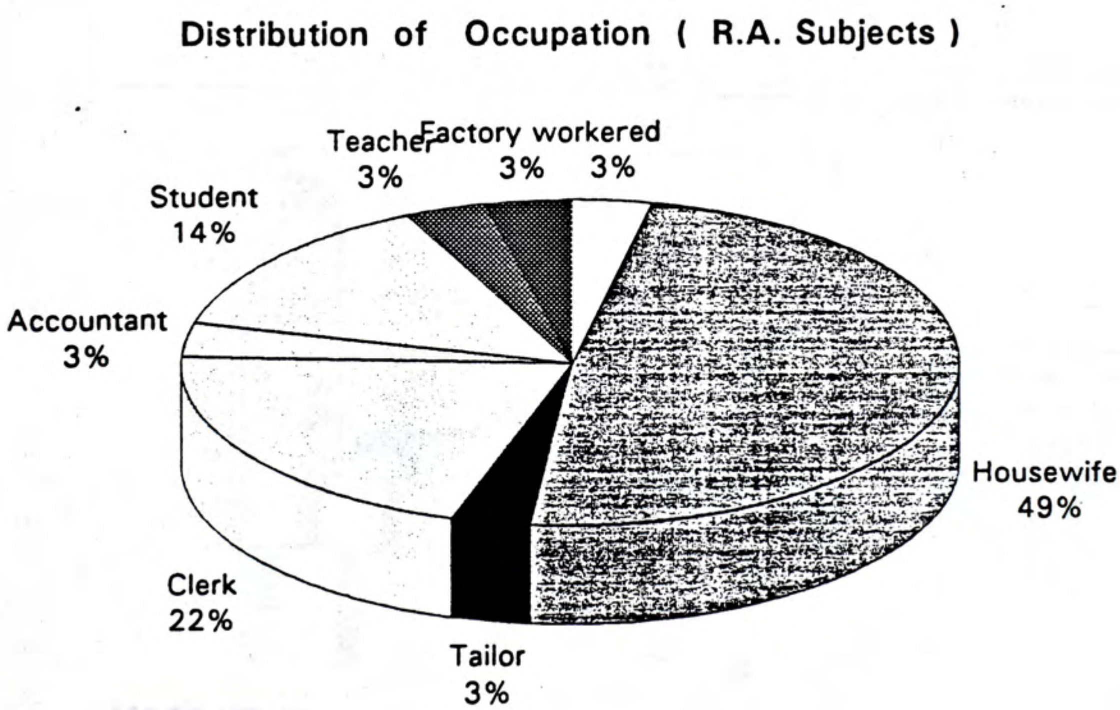
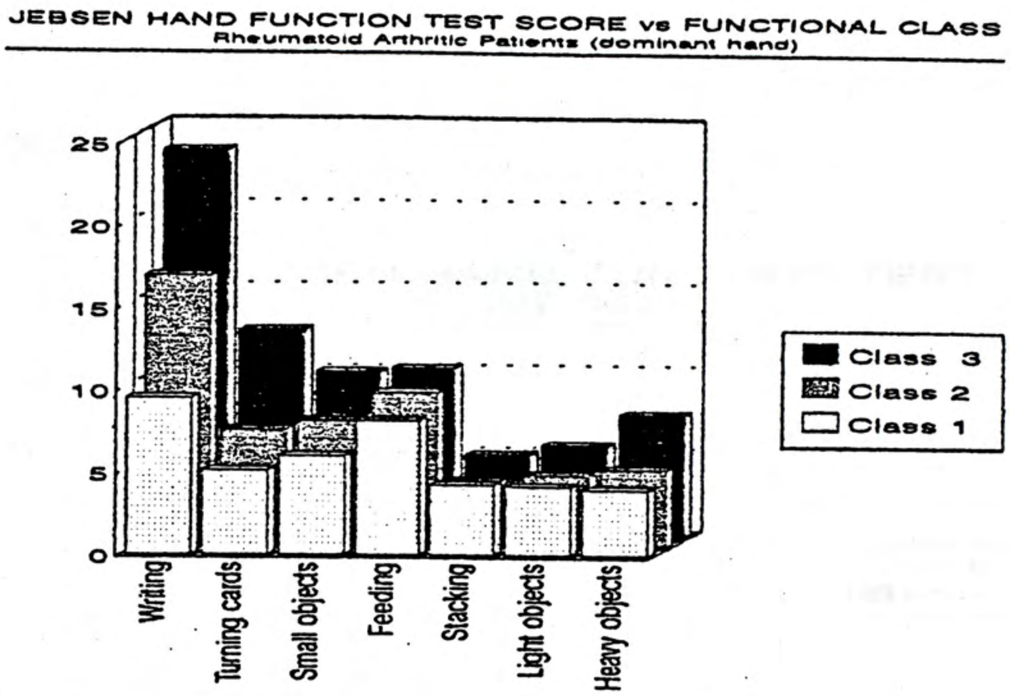


Fig. 6.10 The Distribution of occupation (RA group)

For the rheumatoid arthritic population, the mean time scores on each subtests are higher than the mean score obtained by normal subjects both in dominant and nondominant hand.



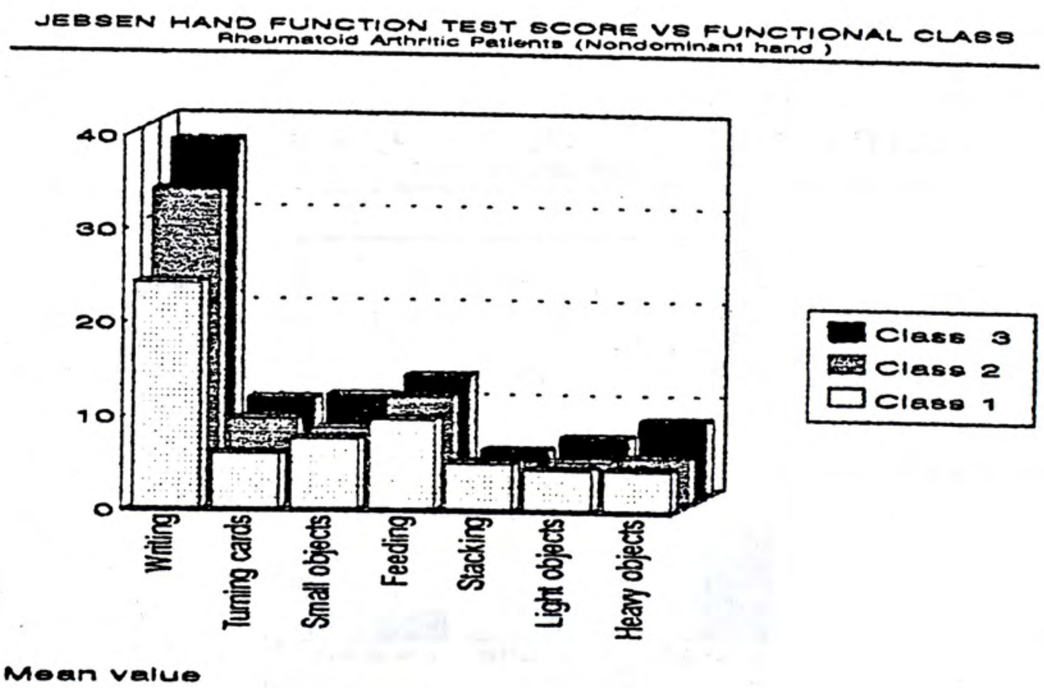
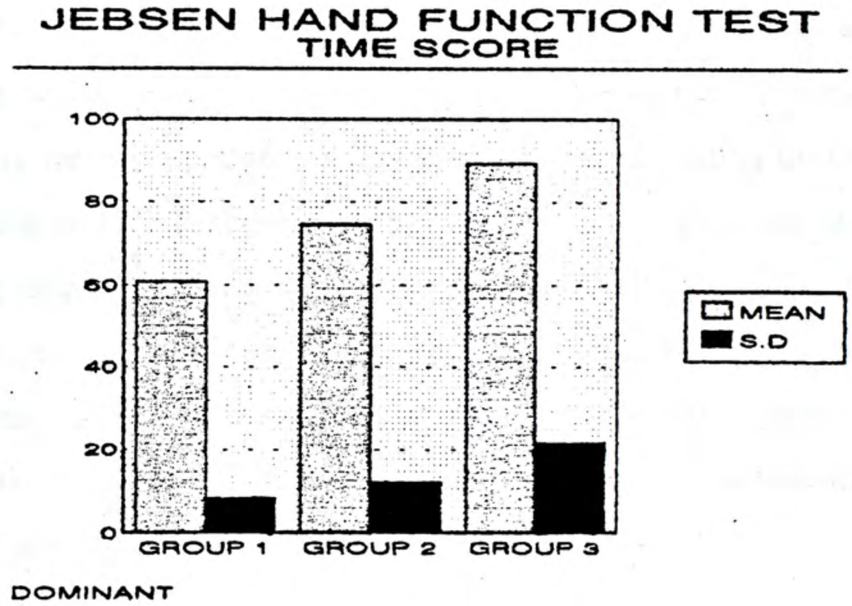


Fig. 6.11 Diagram showing the mean values of time scores in each functional group(dom & non-dom)

For the rheumatoid population, there is a strong correlation between the functional class of the client and the time score shown from the statistical Kruskal-Wallis 1-way ANOVA test. The Jebsen time score on the dominant hand has a correlation 0.0003 (chi-square =16.41). The Jebsen time score on the nondominant hand has a correlation 0.005 (chi-square =10.61) for 29 cases. The following diagram illustrates the distribution of time score for the three functional classes.



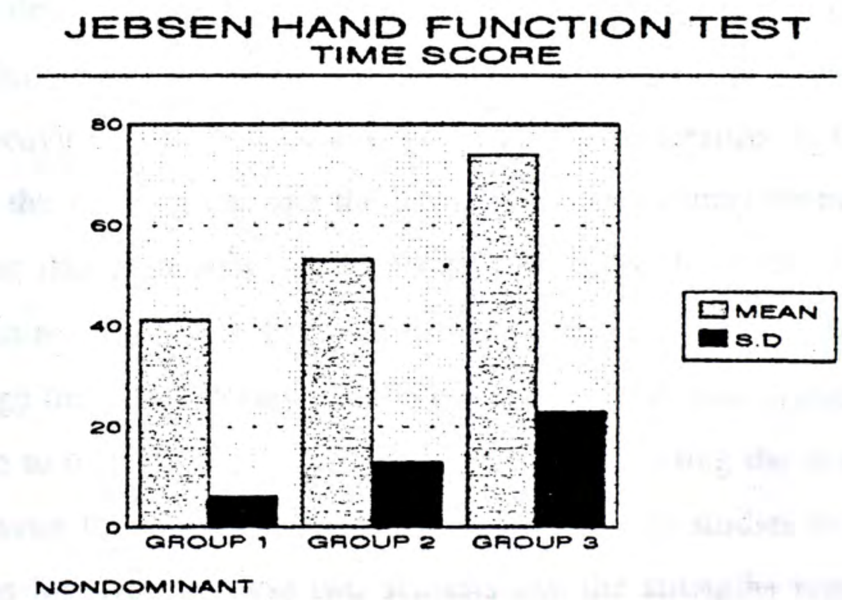


Fig. 6.12 The mean total score (S.D.) of the three functional groups

6.5.6 Discussion

55 normal subjects and 29 rheumatoid arthritic patients with different functional class were selected for this study. The same test equipment and materials are adopted for use in the local situations. The instructions were translated into the Chinese version but the meaning remains the same. The written English sentences were put into written Chinese characters. This provided a valid assessment environment for all clients. The mean scores between the US population and the Hong Kong population does not show a significant difference from the graphical presentation.

The results indicated that the mean scores of the rheumatoid arthritic clients are higher than the normal subjects. Among the 29 rheumatoid clients, they were divided into 3 functional classes according to the X-ray classification and the functional evaluation as listed in appendix II. There is a strong correlation between the functional level of clients and the total time score both on the dominant and non-dominant hand. (level of significance: dom. = 0.0003, non-dom. =0.005). This further substantiates that the Jebsen Hand Function Test can measure different functional performance of clients.

However, detailed analysis reflected that the difference is more significant on the writing test, the card turning test, the small object test, feeding test and the heavy objects test. There is very little difference in the time scores on the stacking test and the light object test. It may be explained by the fact that both tests are involving picking up light materials i.e. small chess and light cans that even patients with very severe deformities can manage the tasks. It may also be due to the short time frame (about 3 seconds) so that the reaction time of therapist in pressing the stop match may influence the outcomes of measurement. Further studies to analyse the motion involved in these two subtests and the strengths required to carry out the motion, are needed.

6.5.7 Limitation of the study

Although the study covers 55 subjects and 29 rheumatoid arthritic subjects, the selection is not randomised. Therefore, the inference to the whole population of Hong Kong people is low. It is the same for the rheumatoid arthritic patients. Further studies to standardise the testing procedures and the collection of the local norms would be beneficial. For the rheumatoid patient group, other factors have to be considered including the number of finger joints affected, the stage of the diseases process, other therapeutic intervention prior to the test etc which may influence the outcomes of measurements. This study could only provide the researcher with a preliminary understanding of the validity of the test.

6.5.8 Conclusion

The Jebsen Hand Function test(Jebsen, Taylor, Trieschmann, Trotter & Howard, 1969) was designed as a measurement tool of hand function and is widely used by occupational therapist overseas. In Hong Kong, this is the first study to standardise the test items. This test is then used to compare the functional performance of our rheumatoid arthritic clients. The results of the tests correlate strongly to the X-ray classification system and the functional evaluation system (Ropes , 1958) It provides an objective quantitative measurement for hand function and the data can be analysed using computerised statistical packages. Therefore, the investigator has adopted this test as a measurement tool to compare the hand functions of rheumatoid arthritic before and after splint intervention programme.

6.6 Assessment of functional range of motion

A preliminary study has been conducted to analyse the range of motion at the proximal interphalangeal (PIP) joints and the metacarpal phalangeal (MCP) joints of finger during functional activities using the electro-goniometer.

6.6.1 Aims of the study

a. to analyse the functional range of motion of the PIP joint and the MCP joint in performing the Jebsen-Taylor Hand Functions test

b. to compare the functional range of motion between a RA subject with flexion contracture at PIP joint and a normal subject

6.6.2 Methodology

One normal subject and one rheumatoid arthritic patient are selected for the study. They are selected with similar age, occupation, and body built. The rheumatoid arthritic patient has a flexion contracture of 45 degrees at the PIP joint of the right middle finger. Each subject will be instructed on the procedures of test.

The finger goniometer will then be attached at the right middle PIP joint as shown in the diagram. The Jebsen Taylor hand function test was tabled and the subject is asked to carry out the seven subtests respectively. The recordings would be transferred to computer for analysis.

6.6.3 Results

Two subjects are selected for this preliminary study. Both subjects age between 50-55 are female housewife. Subject one being the normal subject and subject two suffered from rheumatoid arthritis for 5 years with flexion contractures at PIP joint (45 degress)on the right middle finger.

The following tests were conducted:

a. Measurement of static active range of motion using minigoniometer

b. Measurement of Jebsen Hand Function test

c. The seven subtest are repeated with the electrogoniometer connected to the PIP joint or MCP joint of right middle finger

Both subjects were very co-operative during the test procedures. Seven subtests were conducted on the same day to the same subjects respectively.

a. Time score for each subtest vs subject

Subtest	Normal subject(s)	RA subject(s)
Writing	13.21	16.24
Turning cards	5.12	14.11
Picking up small objects	5.77	12.31
Simulated Feeding	8.89	15.21
Stacking chess	3.82	4.85
Picking light cans	5.55	10.12
Picking heavy cans	5.97	11.42
Total	48.33	84.26

Table 6.3 **Table showing the time score for each subtest for normal and RA subjects**

b. Active range of motion

	Normal subject	RA subject
Active Range of Motion	0-135	45-95

Table 6.4 **Table showing the active range of motion for RA and normal subject during hand function test**

c. The functional range of motion for conducting the seven Jebsen-Taylor Hand Function Test between a normal subject and a RA patient are tabulated as follows:

Jebsen Taylor Hand Function Test	Metacarpophalangeal joints (MCP)		Proximal Interphalangeal joints (PIPjoints)	
	Normal sub.	RA sub.	Normal sub.	RA sub.
Writing	75-85	30-55	50-60	50-90
Turning Cards	20-50	-5-30	10-40	40-80
Picking Up Small Objects	30-60	0-45	50-60	45-80
Simulated Feeding	55-70	20-40	25-45	65-85
Stacking chess	30-50	20-30	20-30	50-80
Picking up light cans	20-40	-5-15	20-40	55-80
Picking up heavy cans	10-35	-10-20	20-40	55-90

Table 6.5 Table showing the functional range of motion between the Normal and RA subject

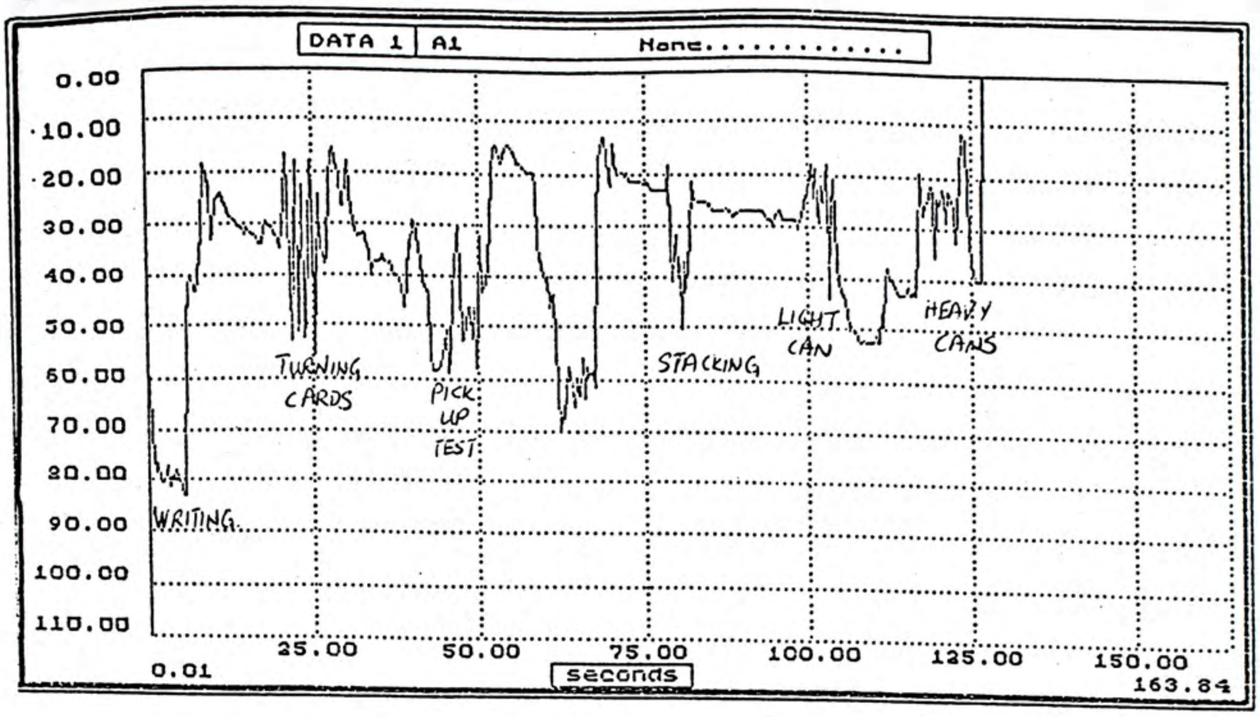


Fig. 6.13 The Functional Range of Motion at MCP joint (Normal subject)

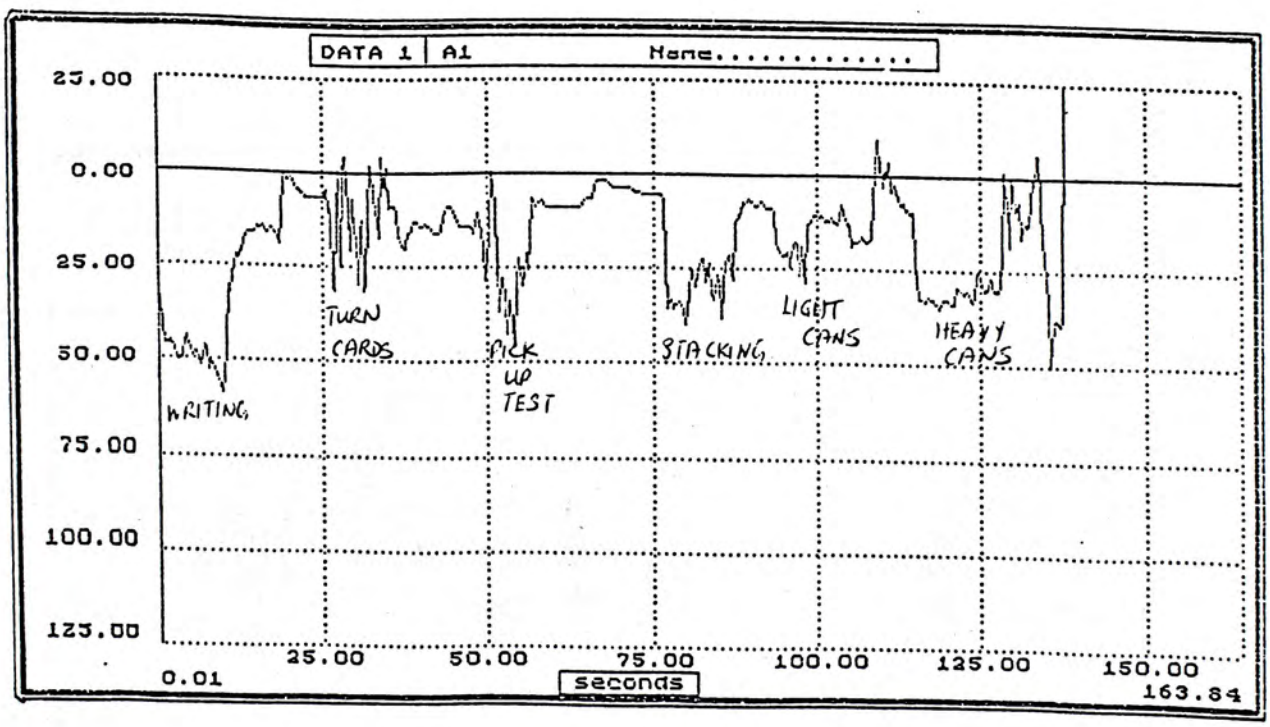


Fig. 6.14 The Functional Range of Motion at MCP Joint (RA subject)

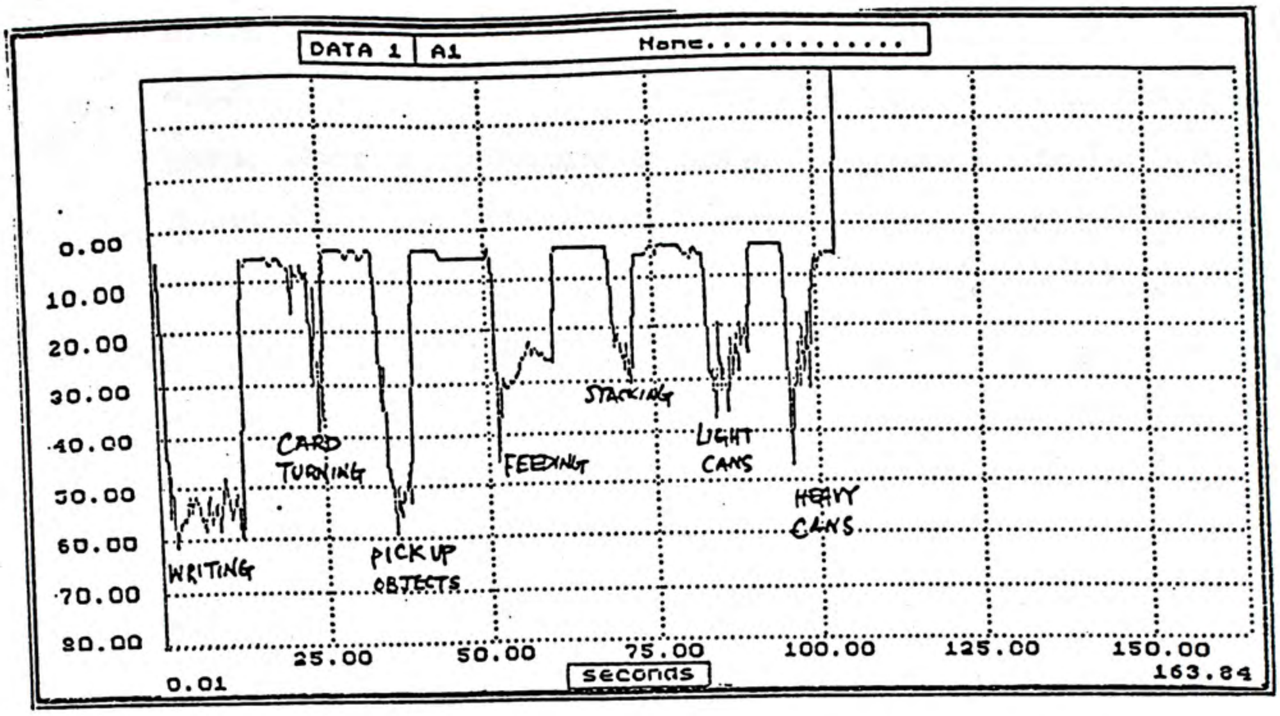


Fig. 6.15 The Functional Range of Motion at PIP joint (Normal subject)

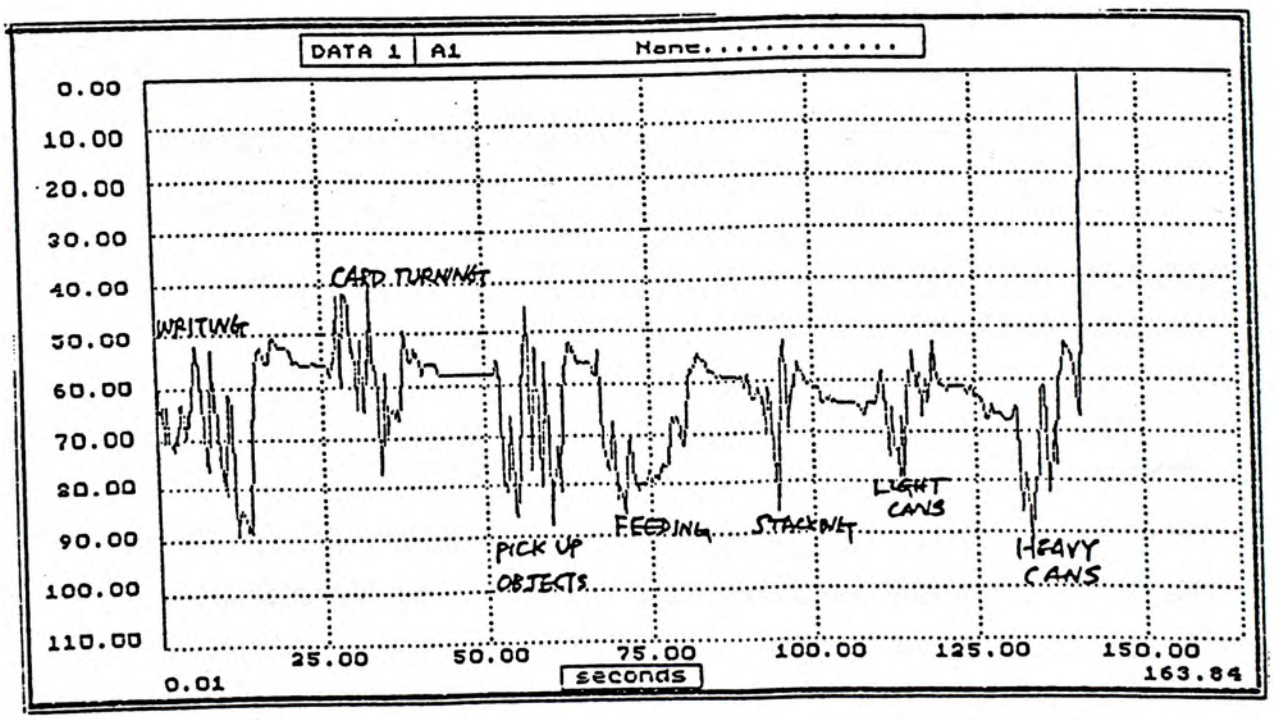


Fig. 6.16 The Functional Range of Motion at PIP Joint (RA subject)

6.6.4 Discussion

Although this is a preliminary study and the samples of subjects was small, it still can reflect how the flexion contracture of the PIP joint can affect the functional range of motion of the joint and the adjacent MCP joints. There is an increase in flexion movement of the PIP joint as reflected from the findings indicating that the finger tends to flex more. The MCP joint has no hyperextension deformity at rest but there is a tendency to extend more frequently during the functional movements as a compensation for the loss of the extension range at the PIP joint. The MCP joint is hyperextended to 10 degrees when the RA subject is asked to lift the heavy cans.

The goniometer was able to record the hand prehension from reaching, grasping and release. From the experiment, the RA subject also shows difficulties not only in reaching, grasping but also shows delay in release. These may be the main reasons that the total time score is lower than the normal subjects.

6.6.5 Limitation of the study

The number of subjects is too small for any statistical analysis and deduction. Human error may exist in positioning the two poles of the goniometer and this may affect the readings and recording. The calibration procedures remain difficult for rheumatoid arthritic patients. The goniometer cannot be used to measure the DIP joint due to the limitation of the poles. It is difficult to align the axis of motion on finger joints and there is a gliding of skin during motion. The two poles of the goniometer are extremely sensitive and should be carefully fixed or removed from the finger. Therefore, the test is time consuming. It has to be connected to a computer for transfer of data. Data cannot be stored for longer than a day due to runout of battery of the data logger. This creates a lot of technical limitation for clinical studies.

6.6.6 Summary

The electrogoniometer is a good standardised device for measurement of active range of motion during functional activities. It can be used to compare the reaching, grasping and release of the hand during functional activities. However, there are some limitations in using the instrument in clinical studies especially since a computer is not available in most out-patient clinics. Therefore, the investigator adopts the use of the minigoniometer in measuring only the active range of motion for the subjects.

6.7 Conclusion

The aims of this study is to develop a comprehensive hand evaluation system for the rheumatoid arthritic patients. The evaluation system will be used to measure the effectiveness of therapeutic intervention for RA clients. In this study, the investigator aims to investigate the effect of corrective splintage for the rheumatoid arthritic clients. A comprehensive hand evaluation system is therefore an important instrument for the project.

Three small scale studies have been conducted in parallel to investigate the reliability and standardisation of the assessment instruments. A series of laboratory and clinical procedures have been conducted.

In the first study, the Jamar dynamometer is found to have a great individual variation from one device to another. The REC prototype grip analyser using the strain gauge is a reliable measurement device for assessment of grip strengths. It can be calibrated every time before the instrument is used for measurement. The readings are recorded is independent of the distance on the dynamometer. Therefore, the investigator has selected this equipment as a protocol measurement of grip strengths in the main study.

In the second study, the Jebsen Hand Function Test was standardised with the same equipment set up and instructions procedures. A local reference

was developed with 55 normal subjects and 29 RA subjects. It reflected the ability to determine the levels of hand functions of clients in an objective method. It is therefore selected for the study.
Finally, the measurement methods for active range of motion are investigated. The Penny & Giles Electrogoniometer is a very sensitive measurement tool and it can test the range of motion during reaching, grasping and release during functional activities. There are still a number of limitation in the device. The investigator therefore decided to select the mini-goniometer in measuring the active range of motion in the main study.

As a conclusion from the three studies, the evaluation system with standard protocol is developed. Each client will be assessed on grip strengths using the REC grip analyser with standard procedure of testing. One trial for each type of grip assessment(power grip, pinch grip, lateral pinch, chuck grip). The Jebsen Hand Functions test is then administered to assess the hand functions of client. The minielectro digital goniometer is used to measure the range of motion of the affected PIP joint. Pain is evaluated using a 10 point visual analog system for reference. This protocol will be adopted throughout the study.

Chapter Seven
The Main Study

7.1 Introduction

Patients suffer from rheumatoid arthritis with onset of more than one year and presence of flexion contracture are selected for the study. They are divided into two groups (1 & 2) using the matched paired control group research design. Initial functional assessments are conducted with both groups of subjects and rated according to standardised methods. They then continue other routine medical treatment including drugs, physiotherapy and occupational therapy. After six weeks of control period, they are re-assessed on the functional assessments. Then for group 1 clients, the dynamic finger extension splint will be tailored made to individual subjects. Similarly the static belly gutter splint will be fabricated to the group 2 subjects. Functional hand assessments are conducted again six weeks after the application of the splints. It is planned to collect 30 subjects for the study to be distributed into two groups.

The subjects are divided into group 1 & 2 on a matched pair manner. The results of the various hand functional assessments will be analyzed critically.

7.2 Research Design

The study is designed to compare the effectiveness of two types of corrective splintage on the flexion contracture of rheumatoid fingers. Since the degree of disabilities vary so much among individual patients with rheumatoid arthritis, it is difficult to compare the results for one patient with another patient. Their functional level, degree of disabilities, and patterns of deformities are so different. Therefore, the results will be compared using the same groups of clients before and after intervention.

The investigator has adopted the matched-pairs control group design for this study. Subjects are paired with similar functional levels, age, sex and the affected finger into the two groups for comparison of the effect. This helps to minimise the discrepancies in hand functional assessments to variation in severity of the disease processes.

Pretest - Post test control group design

M1	------>	S1 ->	A	---->	P1
M2	------>	S2 ->	B	---->	P2

Key:

M1: RA subjects in group 1

M2: RA subjects in group 2

S1: Same group of subjects in group 1 after six weeks

S2: Same group of subjects in group 2 after six weeks

A: Splint intervention - dynamic finger extension splint(capener splint)

B: Splint intervention - static finger extension splint(belly gutter splint)

P1: Group 1 subjects after six weeks of splint intervention

P2: Group 2 subjects after six weeks of splint intervention

7.3 Definition of variables

7.3.1 Rheumatoid arthritis patients:

Patients who are diagnosed as classical or definite rheumatoid arthritis according to the classification system of American Rheumatism Association (ARA) based on the number of characteristic features present.

7.3.2 Finger flexion contracture:

Finger flexion contracture of 15 degrees or more at the proximal interphalangeal joint. Boutonierre deformities or bony ankylosis are excluded. The little finger is also excluded.

7.3.3 Corrective splintage:

Fig 7.1 The Capener Splint (Capener 1967, Wynn Parry 1976, Colditz,1983)

Fig. 7.2 The Belly Gutter Splint (Wu, 1990)

7.3.4 Effect:

The outcome of the overall hand function of clients after six weeks of application of corrective splints. It is measured by:

a) measurement of active range of movements

b) measurement of grip strengths: power grip, pinch grip, chuck grip, pincer grip (affected finger and thumb)

c) measurement of time score in performing the Jebsen Hand Function test

d) pain score

7.3.5 Statement of hypothesis

(1) There is a difference in active flexion and extension at the affected PIP joint six weeks after the application of either splint A and B.

(2) There is a difference in grip strengths (power grip, pinch grip, chuck grip and lateral pinch grip) of the splinted hand six weeks after the application of either splint A and B.

(3) There is a difference in the Jebsen Hand function test score of the affected hand six weeks after the application of either splint A and B.

(4) There is a difference between the application of splint A and B in terms of:

- i) active extension of the affected fingers
- ii) power grip
- iii) pinch grip
- iv) chuck grip
- v) Jebsen hand function test score

7.4 Subject selection

7.4.1 Subjects of either sex will be accepted into the study if they are:

i) aged between 15 and 65,

ii) diagnosed as rheumatoid arthritis with no bony destruction(Appendix I),

iii) with onset greater than one year, at the remission stage,

iv) with finger flexion contracture at Index, Middle or Ring finger(measured from the goniometer with extension lag greater than 15 degrees on active extension) resulting from soft tissue contracture,

v) co-operative with good compliance of treatment

vi) preferably with right hand dominance

7.4.2 The subjects are selected from

a. Rheumatology clinic, General Medical Unit, Queen Mary Hospital,

b. Occupational therapy clinic, Prince of Wales Hospital and

c. Occupational therapy clinic, Queen Elizabeth Hospital.

7.4.3 The subjects are carefully matched with similar functional class, mean year of onset, age, sex, affected finger and hand dominance into two groups for study.

7.5 Experimental procedures

7.5.1 The investigator will pay regular visits to the three clinics. Suitable clients will either be referred by case medical officer or case occupational therapist. The investigator will then explain clearly to each client the aims and objectives of the study. The client if agreed to join this study, has to sign a consent form to comply with the experimental regime(Appendix VII). The clients will then be matched with another client of similar age, year of onset and functional levels.Both clients will then be randomised into either group 1 or 2.

After careful examination and screening, the therapist will record the personal particulars and clinical histories of the patients(Appendix VIII).

For ethical considerations, the selected clients will not be interfered with in terms of the routine medical treatment including drug treatment, physiotherapy and other forms of occupational therapy. The Medical Officer-in-charge has agreed to introduce new forms of medication or treatment during the experimental period only if the subject suffers another episodes of synovitis. The client will then be withdrawn from the study.

7.5.2 Pre-splint assessment is conducted as follows:

a. Assessment of joint range of motion

For each client in both groups, the active range of motion of the affected finger joints including the MCP, PIP and DIP joints are recorded using the electronic small joint goniometer as described in chapter five. Before the test, it will be calibrated to "zero" and patient is asked to fully extend and flex the finger until limited by pain or stiffness.

b. Assessment of grip strengths

Each client will be assessed on their power grip, pinch grip, chuck grip and lateral pinch grip on the affected hand only. The position of testing is illustrated in the diagram. The REC grip analyzer is used for measuring the maximum grip strengths and the fatigue rate of the client.

c. Jebsen Hand Function Test

Each client is asked to carry out the seven subtests of the Jebsen Hand Function Test according to the instructions laid down in appendix VI . The seven subtests include:

(a) writing
(b) turning cards
(c) picking up small objects
(d) simulated feeding
(e) stacking chess
(f) picking up light cans
(g) picking up heavy cans

7.5.3 Splint intervention period

After six weeks of control period, the patient is re-assessed again on the same protocol. The same testing equipment is used. The tester, the instructions remain consistent.

The investigator will follow the same procedure (appendix X) in fabrication of either splint A or Splint B for the particular client. The finished splint will be applied onto the client's hand for checking of its comfort and fitness. The corrective forces cannot be measured objectively but each client is asked to wear the splint for 20 minutes. If client does not complain of any discomfort or increase of pain, then it is considered acceptable. This depends on the professional judgement by the investigator.

Then, they will be instructed on the method of application and wearing time of the dynamic finger splint which is tailored made for each patient. An instruction guideline will be given to each client. The dynamic finger extension splint is to be applied four times a day with interval of two hours on and two hours off. The Belly Gutter Splint is to be worn eight hours a day during night rest. Telephone enquiry is made by investigator once every week to each client with two purposes:

a. to remind them of the splint programme

b. to check any problems arise from wearing the splint

The same procedure is adopted for both groups. At the end of the third week, the client would have an appointment with the investigator to re-check the corrective forces of the splint, and to assess the hand functions following the protocol. This assessment is conducted as a measure in case patient default the six weeks study programme, some baseline records can still be retained.

7.5.4 The final hand function assessment will be conducted six weeks after the application of splint following the same protocol. Client will then be referred back to case occupational therapist for further management.

7.6 Pilot study

A preliminary trial of the study has been conducted on a smaller scale for a period of three months prior to the main study. Four clients with rheumatoid arthritis satisfying the criteria were referred from the occupational therapy department, Prince of Wales Hospital for the study. They were all attending occupational therapy regularly for assessment and training. All patients agreed to comply with the splint protocol after explanation by the investigator.

Each subject is assessed initially as follows:

a. a brief medical and personal background

b. assessment of grip strengths: power grip, pinch grip, lateral pinch grip and chuck grip

c. assessment of hand function : Jebsen Hand Function Test

d. measurement of Active Joint Range of Motion on affected hand.

The client is re-assessed six weeks later following the same assessment protocol conducted by the same therapist. Clients in group 1 will be prescribed with Splint A (Capener splint) and subjects in group 2 will be given a Splint B (Belly Gutter splint). Detailed instructions and application of the splint has been given to the clients. Clients have to sign a consent form agreeing to comply with the splint programme as explained by the investigator for a period of six weeks.

Biweekly assessment monitored each client on the JROM and measurements of grip strengths. The splint was checked for the tension and pressure regularly. After six weeks, the same assessment protocol listed above was conducted again to compare the progress.

7.6.1 Results of the pilot study

There are one male and three females subjects. The age ranges from 24 to 35 years old. The year of onset ranges from one to five years. The male client has the flexion contracture on left middle finger and all other three clients have the flexion contracture on right middle fingers.

The results indicated that the flexion contracture of the affected joint has improved both in group 1 and 2. However, group 1 showed a greater difference in improvement (12.5 degrees). There is very little difference in the pretest measurement.

The active flexion range of the joint remained the same for both clients in group 1 but there is a deterioration of flexion range for the two clients in group 2 indicating that the splint may have exerted some effect on the active flexion. There remains no change in active flexion in the pre-test period.

There are some variations in the grip strengths (power, pinch and chuck grip) in the pretest period (six weeks) showing that there may be other factors affecting the grip strengths. One client from group 2 in particular showed deterioration in grip strengths after the splint programme.

7.6.2 Implications in the Main Study

From the clinical observation and subjective reporting of clients, most patients accept the splint programme (12 weeks) and the compliance is satisfactory.

In group 1, clients found difficulties in applying and removing the static splint. Often, help is needed to adjust the velcro. They also reported problems in adjusting the tension of the strap. In the main study, the investigator therefore marked a line at the strap to indicate the tension of the strap for client reference. One client complained that the splint caused a lot of sweat due to poor ventilation. Therefore, in the main study, soft tubinette is applied onto the finger before the splint is worn.

In group 2, clients reported that after 12 weeks, the spring coil becomes rusty. In the main study, the investigator has adopted stainless piano wire for use. Prefabricated coils with standard sizes are also recommended for use on clients. For the wearing regime, one client reported that she forgot to apply the splint. Therefore, a perceptual chart with three slots per day is developed to remind patient to apply the splint regularly.

For the assessment protocol, clients reported that the assessment on grip strengths were quite strenuous. In the main study, the clients will be given 5 minutes rest prior to this test.

Other assessments have to be considered in the main study:

a. Subjective assessment on joint conditions

b. ADL assessment

c. Pain assessment

d. Patients' feedback on splint design and wearing regime

7.7 Statistical Analysis of Data

7.7.1 For the main study, the following statistical tests are used:

a. The mean difference in grip strengths pre and post test are analyzed using the student paired t-test both in group 1 and 2

b. The mean difference in active range of motion pre and post intervention are analyzed using the paired t-test both in group 1 and 2.

c. The mean difference in the time score on the Jebsen Hand function test pre- and post- intervention are analyzed using the paired t-test.

d. The pain score before and after intervention are compared using the t-test.

e. The results of the two groups in the following five tests are analyzed using student paired t-test.

(1) Active range of motion

(2) Power grip

(3) Pinch grip (affected hand)

(4) chuck grip

(5) lateral pinch grip

f. The mean differences on the Jebsen Hand function test score between the two groups are analyzed by the student paired t-test. The results are analyzed and interpreted using the statistical package SPSS/PC for IBM personal computer.

Chapter Eight
Results

8.1 Introduction

After the pilot study, the investigator has modified some assessment procedures by introducing the pain assessment using the 10 point visual analog scale. Interviews are also conducted to gather patients' feedback on the splint programmes. Individual assessment area is assigned at one corner of the clinic for the study.

The protocol of assessment was modified and the main study was started in May, 92 until December, 92. Thirty rheumatoid arthritic patients were selected carefully and were paired according to the functional classification, age and years of onset into two groups. Six patients were withdrawn from the study due to the exacerbations of the diseases. Twenty four clients completed the course of study in 12 weeks.

Initial assessments were conducted with the assessments of active range of motion, measurements of power grip, chuck grip, lateral pinch grip and pinch grip(between affected finger and thumb), Jebsen hand function tests and pain level. Similar assessment procedures were repeated for the 24 clients after six weeks. They were then grouped into two groups matching their functional class, age and sex.

For clients in group 1 the dynamic finger extension splint was fabricated for each client whereas for group 2, the static belly gutter splint was fabricated. Each client was instructed on the proper wearing methods and regimes. After six weeks of intervention, the clients were re-assessed using the same assessment protocol. The results were then compared with the initial assessment scores.

For ethical considerations, all clients were allowed to continue other forms of medical treatment including drug therapy, physiotherapy and occupational therapy. Among the subjects, all clients had regular medication for the disease. Only five clients attended out-patient physiotherapy for hydrotherapy and exercise therapy but no specific treatment on the affected hand. Among the six clients attending occupational therapy, only one client had active mobilisation programme both upper limbs and lower limbs. The other five clients were on regular follow up once every three weeks. For the purpose of the study, they were requested to stop other splint intervention programme over the affected hand for the twelve weeks upon approval from case medical officers and occupational therapists.

8.1.1 Age distribution(n=24)

Mean	S.D.	Minimum	Maximum
37.08	16.24	16	70

Table 8.1 Mean value and S.D. of age in the sample group

The average age distribution among the twenty four clients is 37 years with a standard deviation 16.24 years. The youngest client is 16 and the oldest is 60 years old.

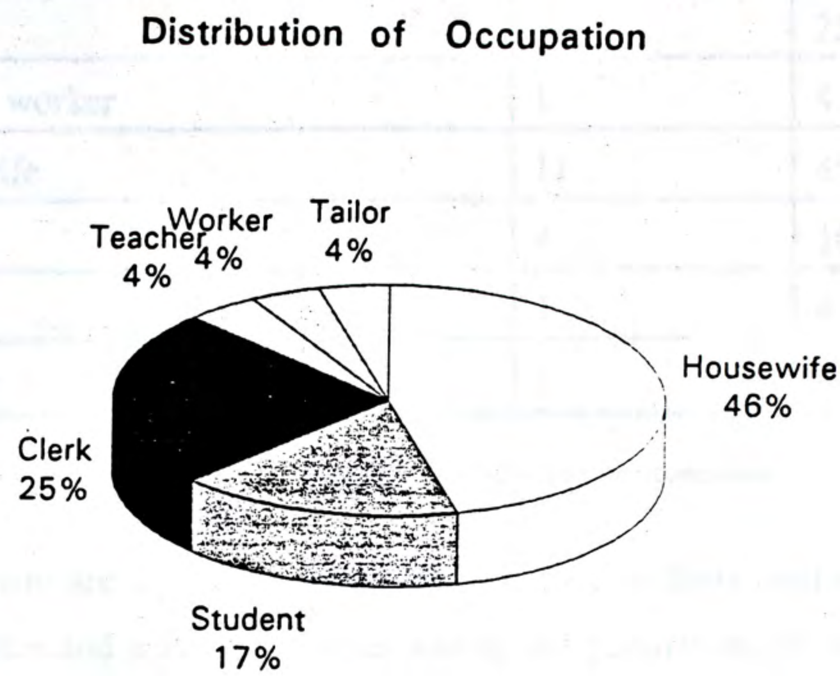


Fig. 8.1 Distribution of occupation among subjects

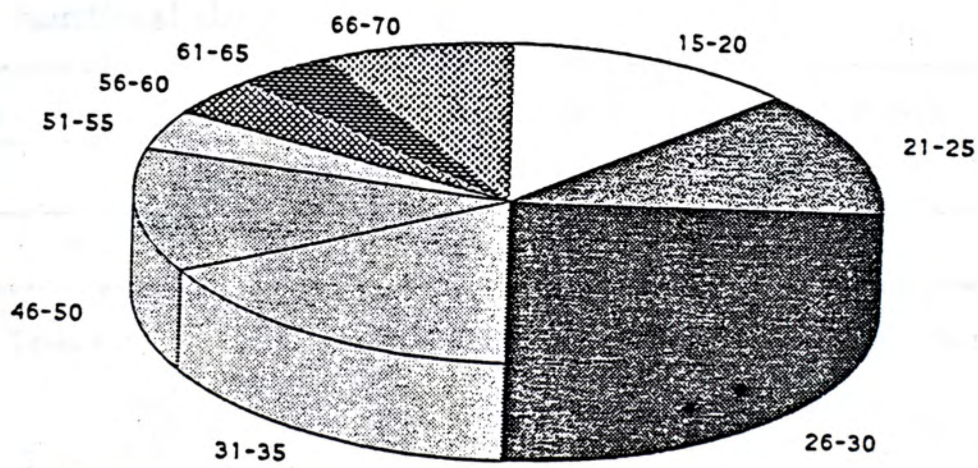


Fig. 8.2 Age distribution of the subjects

8.1.2 Occupation(n=24)

Occupation	Frequency	Percentage
Clerk	6	25
Factory worker	1	4.2
Housewife	11	45.8
Student	4	16.7
Tailor	1	4.2
Teacher	1	4.2

Table 8.2 Table showing the distribution of occupation

There are 11 housewives, 6 clerks, four students, and one teacher, one tailor and a factory worker among the population. In order to have the matched pair design, the clerk, the students, the tailor and the teacher are grouped into one category as the work demand is more sedentary. The factory worker and the housewives are classified into another category as their work are more strenuous. Each group will have equal number of clients in the same category.

8.1.3 Functional class(n=24)

Class	Frequency	Percent
2	17	70.8
3	7	29.2

Table 8.3 Table showing the frequency and percentage of functional class per group

There are 17 clients classified as class II and 7 clients as class III on the functional class system and the X-Ray classification.

8.1.4 Group Characteristics(n=24)

Characteristics		Group 1(n=12)	Group 2(n=12)
Functional class: (no.)	II III	8 4	9 3
Mean year of onset (S.D.)/yr.		6.5(2.5)	5.5(2.0)
Mean age(yr.)		34.25	37.16
Sex distribution: (no.)	female male	11 1	11 1
Affected Hand: (no.)	right left	10 2	9 3
Affected finger: (no.)	index middle ring	5 6 1	5 6 1
Hand dominance: (no.)	right left	12 0	12 0

Table 8.4 **Table illustrating the distribution of sex, age, year of onset, affected hand, finger and hand dominance in each group**

There is an even distribution of sex, hand dominance, affected hand and finger in both groups. There is a slight difference on the distribution of functional class(1 in each group) and the mean year of onset(1 yr) but it is not significant from statistical calculation.

8.1.5 Comparison of the effect of corrective splints on hand functions of clients

The paired T-test is used to analyse the mean difference of the group(n=24) before and after the splint intervention programme.

a. Active Range of Motion after either type of splint intervention

Total number of subjects (N)=24

	Pre-test(a)	Splint prog.(b)	Post test(c)	% diff. (c-b)/b x 100%
Flexion contracture	34.2 + 11.6	34.2 + 11.6 (p=1.00)	15.8 + 10.7 (p=0.001)	54.1%
Active finger flex.	87.6 + 8.2	89.0 + 7.7 (p=0.158)	95.0 + 8.72 (p=0.001)	6.7%

Table 8.5 Table showing the mean values of range of motion before and after splint intervention

The result showed that there is a significant improvement in correction of flexion contracture at the PIP joints (p= 0.001). This substantiated the hypothesis that the application of splintage (both dynamic and static) showed significant difference in correcting the flexion contractures of the affected PIP joint.

*The result reflected that there is no signigicant deterioration of active flexion after the splint programme, but a significant improvement in active flexion of PIP joint after the splint intervention (p=0.001). This reflected that the splint did not limit the active flexion of the PIP joint as substantiated by Spyker (1969) who stated that immobilisation would minimise the active range of motion initially.

b. Grip strengths after splint intervention

	Pre-test(a)	Splint prog.(b)	Post test(c)	% diff. (c-b)/b x 100%
Power grip (n=24)	11.23+8.2	11.05+7.9 (p=0.41)	12.08+8.5 (p=0.001)	54.1%
Pinch grip (n=24)	2.44+1.6	2.56+1.72 (p=0.334)	2.86+1.6 (p=0.002)	15.2%
Chuck grip (n=24)	3.24+1.9	3.16+1.9 (p=0.268)	3.86+2.1 (p<0.001)	27%
Lateral grip (n=24)	3.20+1.4	3.35+1.5 (p=0.083)	3.82+1.6 (p=0.001)	14%

Table 8.6 Table showing the mean values and Standard Deviation of power grip, pinch grip, chuck grip and lateral pinch grip on day 1, before and after splint intervention

There are significant differences in power grip($p=0.001$), pinch grip($p=0.002$), chuck grip($p<0.001$) and lateral pinch grip($p=0.001$) before and after splint intervention. The difference in power grip ($p=0.41$), pinch grip ($p=0.334$), chuck grip ($p=0.268$) and lateral pinch ($p=0.083$) is not significant during the control period showing that improvement was not from other forms of medical intervention which is assumed to be a constant factor during the twelve weeks of study.

c. Jebsen Hand Function Test score after splint intervention

(Time score per seconds)

	Pre-test(a)	Splint prog.(b)	Post test(c)	% diff. (c-b)/bx100%
Total score (n=24)	53.49+12.7	52.27+10.8 (p=0.108)	46.24+9.9 (p<0.001)	11.5%
Pick up test (n=24)	8.86+2.3	8.49+2.3 (p=0.1)	7.34+2.1 (p<0.001)	13.5%

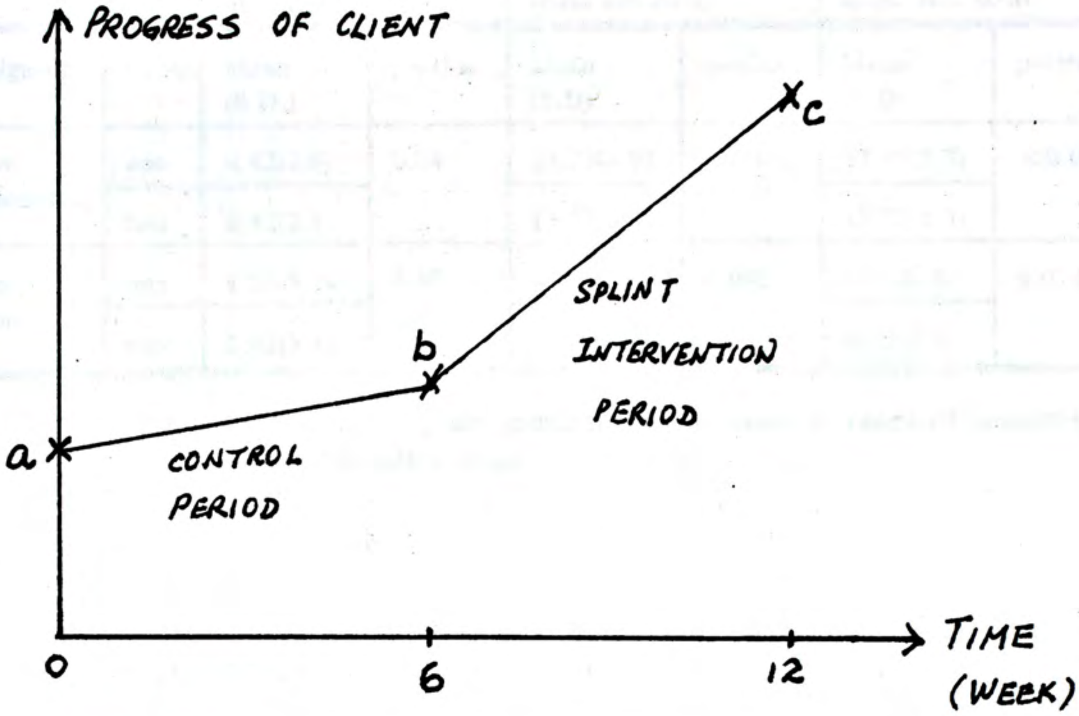
Table 8.7 **Table illustrating the total time score and the pick up test score on day 1, before and after splint intervention.**

The result reflected that clients showed a significant improvement in performing the Jebsen hand function test($p<0.001$) after splint intervention programme. The difference during the six weeks control period is not significant ($p=0.108$).

The result also reflected that there is a significant difference in the subtest related to picking up small objects indicating the significant improvement in dexterity skill of the affected finger in this particular subtest.

8.1.6 Comparison of the effect of two types of corrective splintage on hand functions of clients

a. **Schematic illustration of the assessment procedures**



The following results showed the difference in outcomes of the two different types of splint designs.

The Student's t-test is used to measure whether there is significant difference between two types of corrective splints: the Capener Splint(I) and the Belly Gutter Splint(II) from the assessment protocol on hand functions. The level of significance is set at 0.05. The following results are summarised:

b. Active Range of Motion on the affected PIP joint

		Mean diff between initial and pre-splint asst. (b-a)		Mean diff. between pre-splint and post splint asst.(c-b)		Mean diff. between initial asst.and Post splint asst. (c-a)	
n=12/group	Group	Mean (S.D.)	p-value	Mean (S.D)	p-value	Mean (S.D)	p-value
Flexion contracture	one	0.42(2.6)	0.34	23.33(4.9)	<0.001	23.75(5.7)	<0.001
	two	0.42(2.6)		13.33(5.4)		13.75(4.3)	
Active Flexion	one	1.25(5.7)	0.93	8.75(4.3)	0.002	10.0(6.0)	0.014
	two	1.42(3.1)		3.33(3.3)		4.75(2.3)	

Table 8.8 Table showing the group mean difference in range of motion before and after intervention

For the correction of flexion contracture at the PIP joint, both groups showed significant improvement after the splint intervention programme($p<0.001$) However, by comparing the mean difference between the two groups, group 1 showed a better result than group 2. There is no significant difference($p=0.34$) between the initial assessment and the pre-splint assessment for both group 1 and group 2.

Further analysis from the graph in fig. 8.3 showed that one client in group 2 was able to achieve zero degree of correction but no single client could achieve full finger extension in group 1.

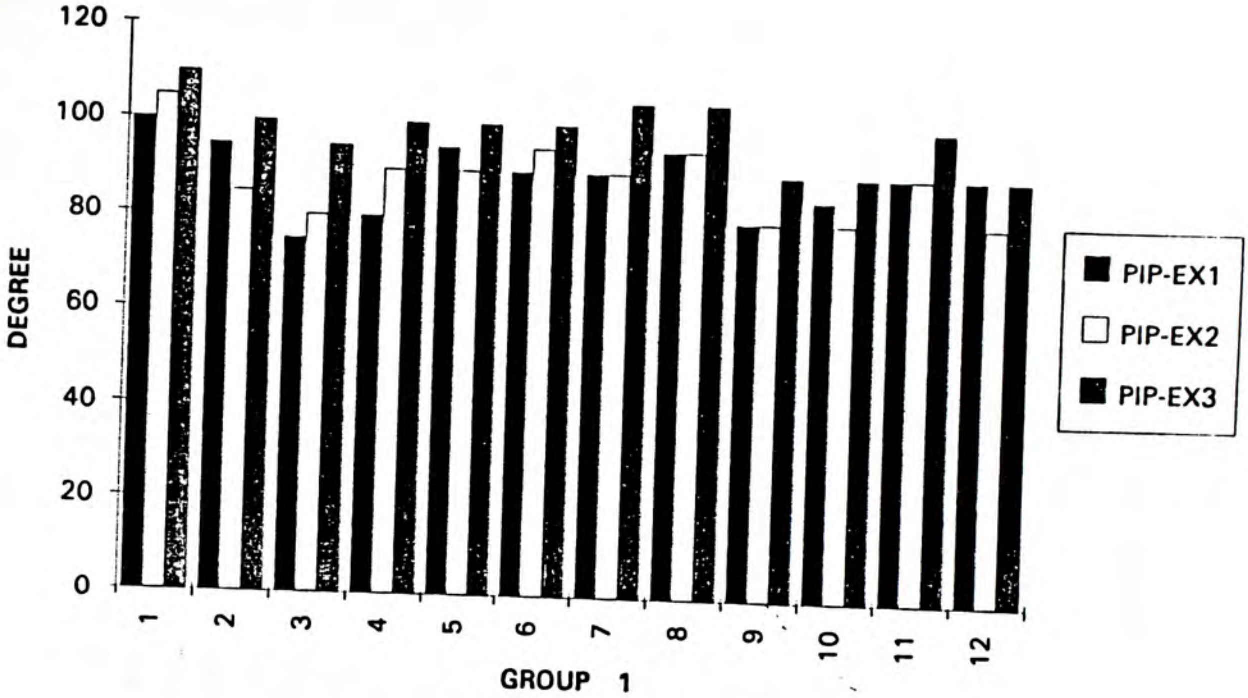


Fig. 8.5 The change of active flexion with time (Group 1)

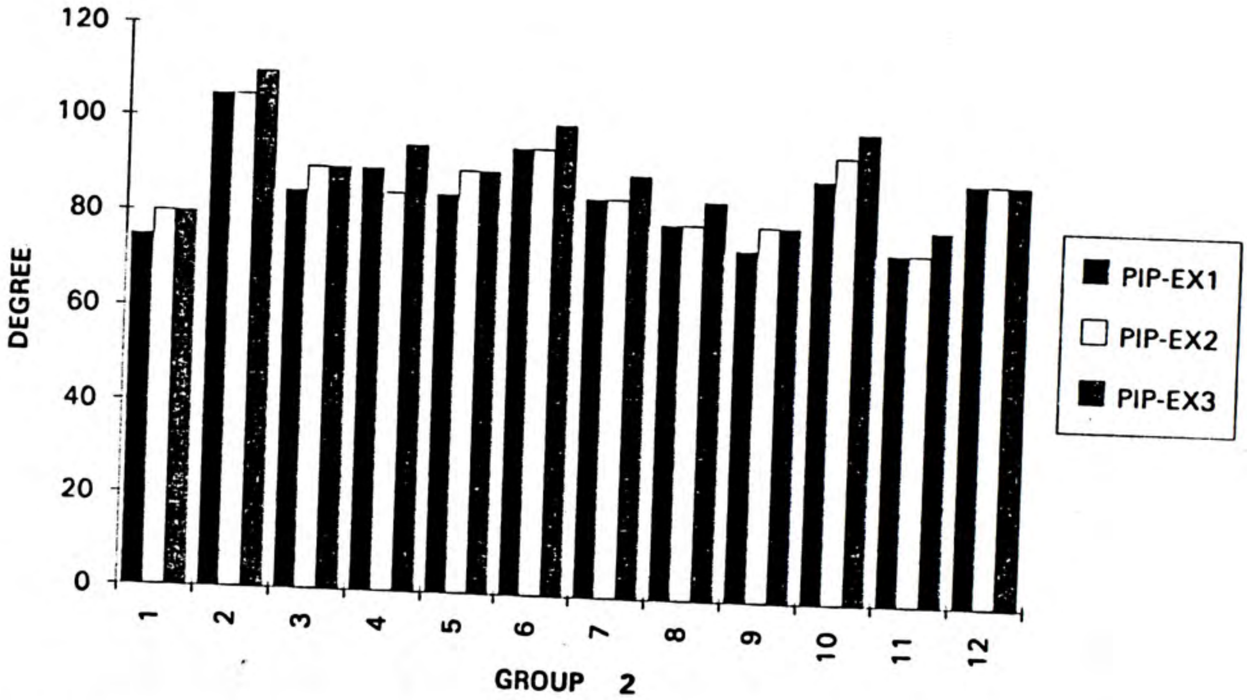


Fig. 8.6 The change of active flexion with time (Group 2)

Key(for fig 8.5 & 8.6):

PIP_EX1 Active flexion of PIP joint measured 6 weeks before splint application

PIP_EX2 Active flexion of PIP joint measured the day of/ before splint application

PIP_EX3 Active flexion of PIP joint measured six weeks after splint application

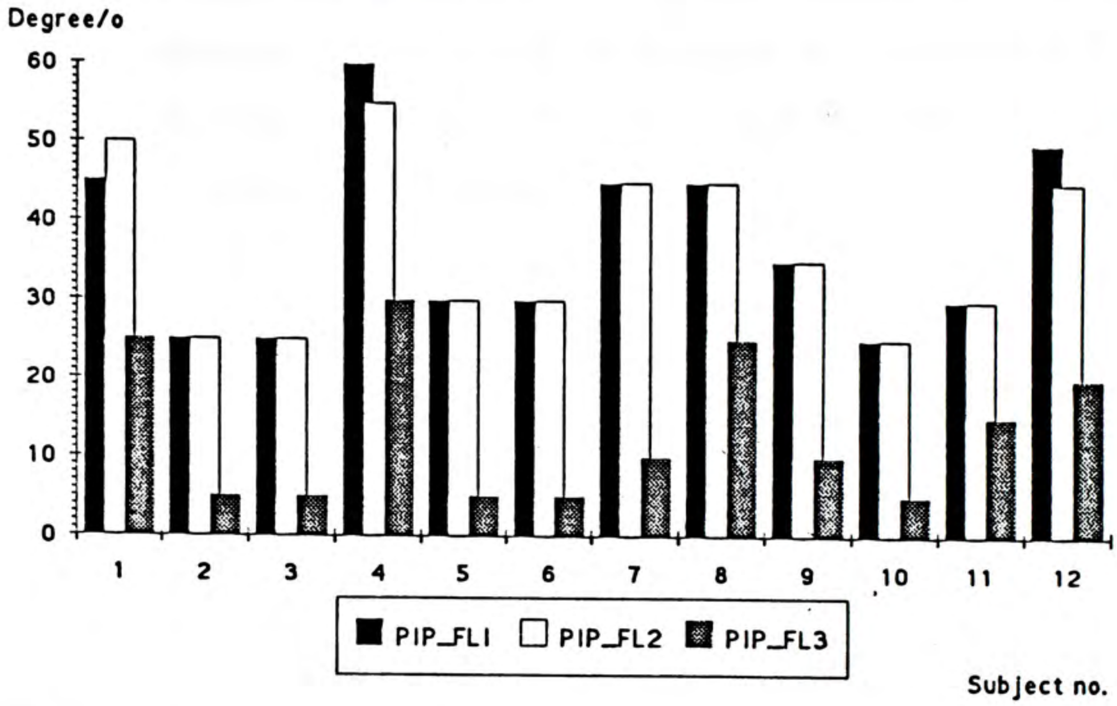


Fig. 8.3 The change of flexion contracture with time (Group 1)

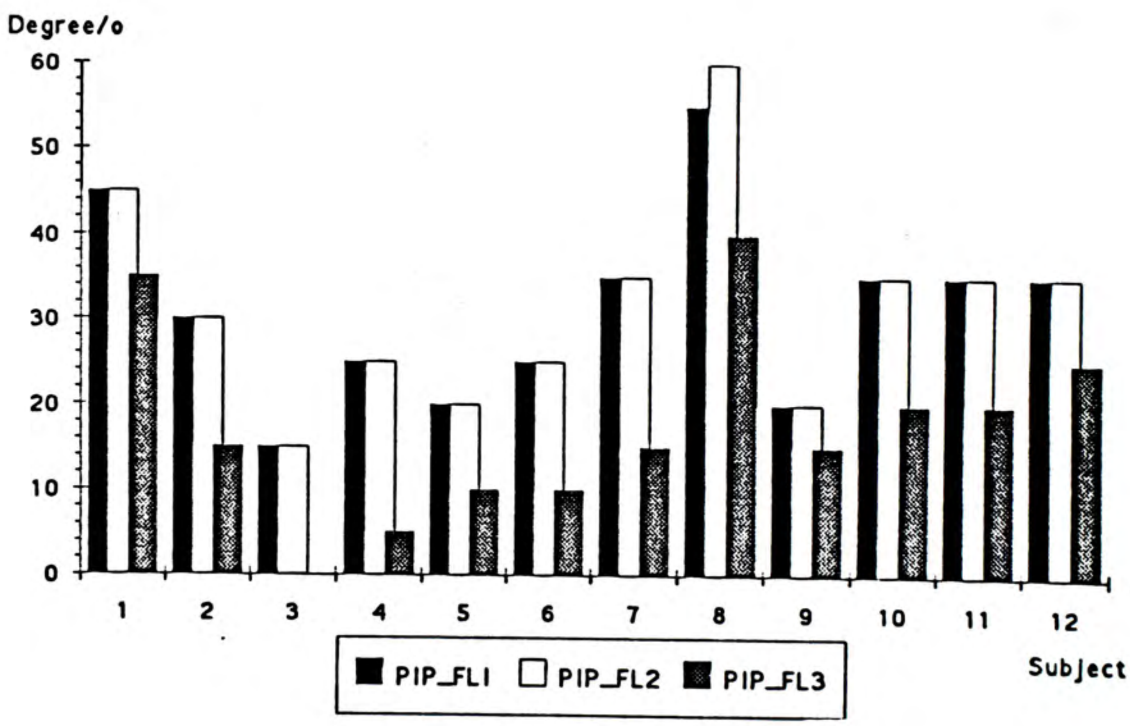


Fig. 8.4 The change of flexion contracture with time (Group 2)

Key (for fig 8.3 & 8.4) :

PIP_FL1	**Flexion contracture of PIP joint measured 6 weeks before splint application**
PIP_FL2	**Flexion contracture of PIP joint measured the day of/before splint application**
PIP_FL3	**Flexion contracture of PIP joint measured six weeks after splint application**

c. For the active flexion of the PIP joint, there is no significant difference during the presplint period (0.93) in both groups but the difference is marked ($p<0.05$) after splint intervention. The mean difference in group 1 (8.75) is higher than in group 2 (3.33) showing that Splint 1 is more effective in improving active range of motion both in flexion and extension.

d. Comparison of grip strengths before and after intervention of splint

Total number of subjects: 12 per group

		Control period		Intervention period		Post splint	
n=12/group	Group	Mean (S.D.)	p-value	Mean (S.D)	p-value	Mean (S.D)	p-value
Power Grip	one	0.15(1.3)	0.89	1.32(1.7)	0.23	1.42(1.7)	0.144
	two	0.21(0.8)		0.74(0.9)		0.5(1.1)	
Pinch Grip	one	0.14(0.3)	0.74	0.85(0.6)	0.06	0.98(0.6)	0.06
	two	0.11(0.2)		0.3(0.7)		0.4(0.8)	
Chuck Grip	one	0.29(0.4)	0.128	0.96(0.7)	0.049	0.99(0.5)	0.004
	two	0.2(0.3)		0.46(0.4)		0.26(0.6)	
Lateral pinch	one	0.04(0.3)	0.175	0.58(0.6)	0.25	0.62(0.6)	0.995
	two	0.27(0.5)		0.35(0.3)		0.61(0.4)	

Table 8.9 Table showing the comparison of the mean differences of grip strengths before and after splint intervention between group 1 & 2.

There is no significant difference between group 1 and 2 in power grip, pinch grip and lateral pinch grip ($p>0.05$). However, there is a significant difference in chuck grip ($p<0.05$). The clients in group 1 had greater improvement than in group 2. When comparing the pinch grip between two groups, although it is not significant statistically ($p=0.06$). From the graphical presentation, there is a difference in the mean difference of the two groups. Group 1 had shown better improvement than group 2. However, the level of significance is not proven by statistical analysis.

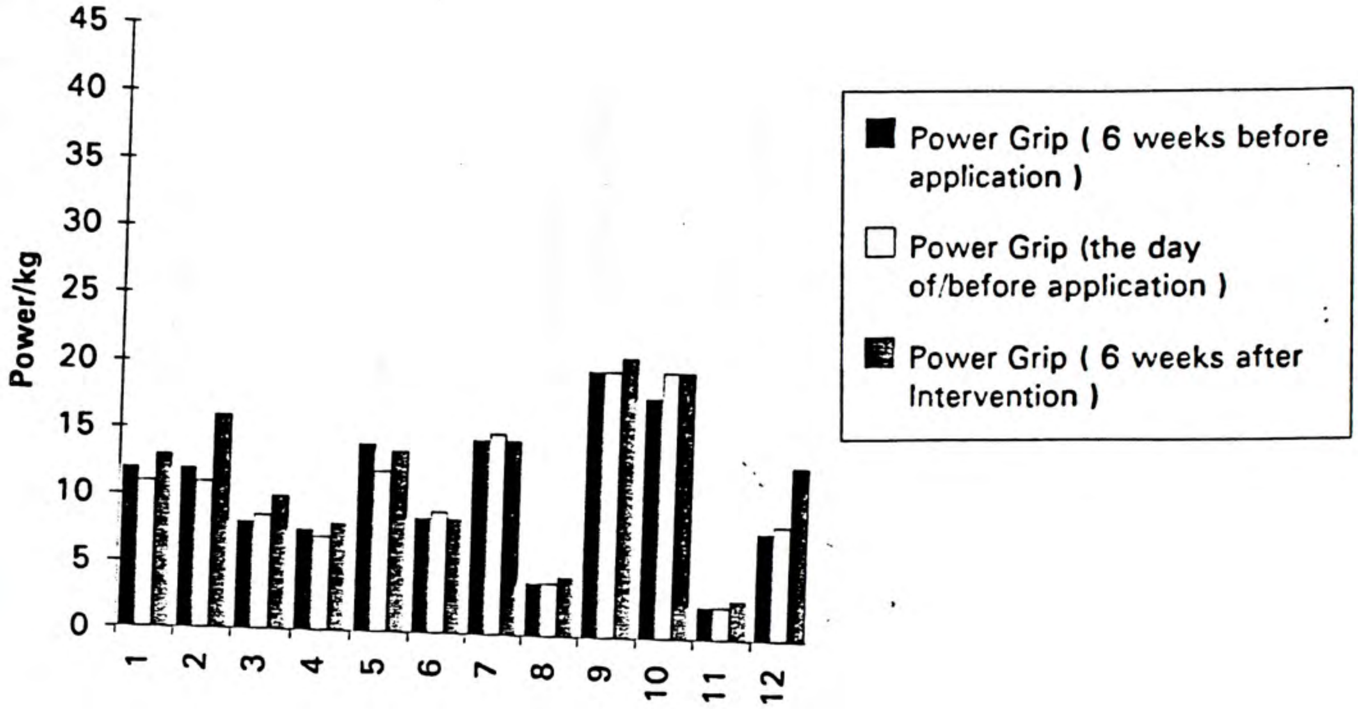


Fig 8.7 The change of power grip of affected hand with time (Group 1)

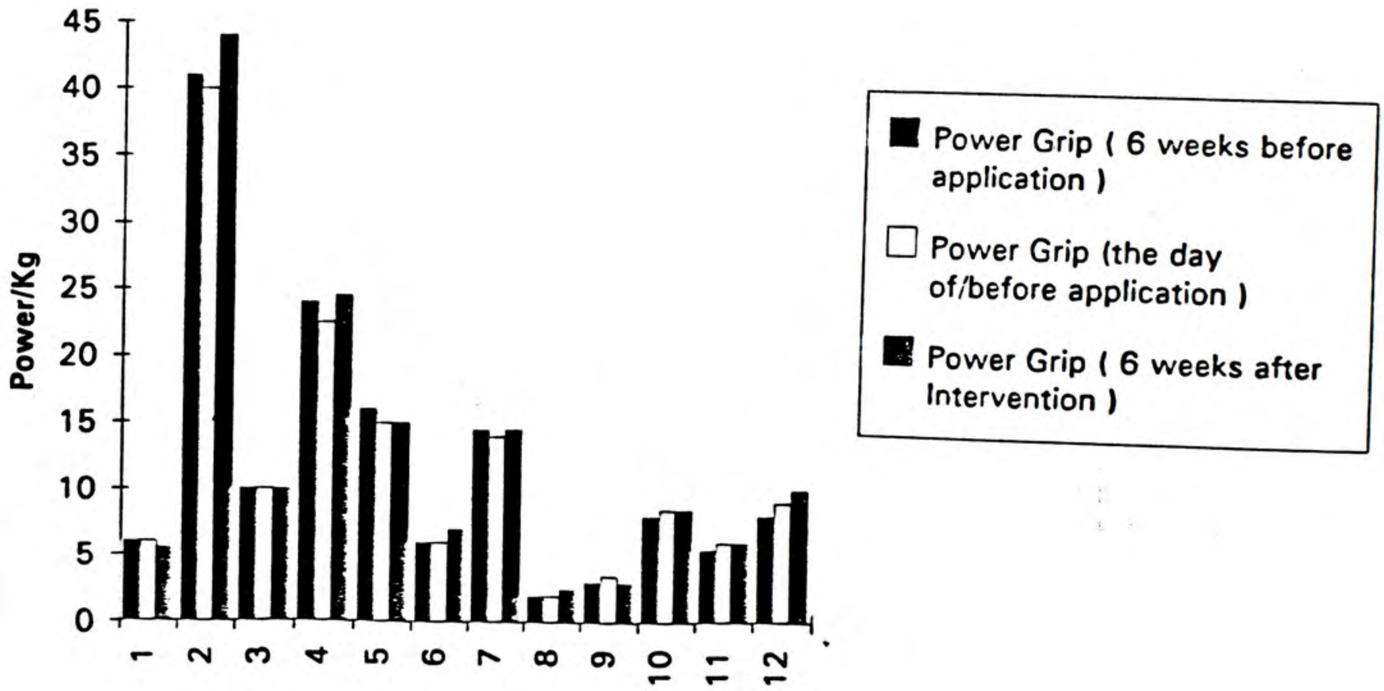


Fig. 8.8 The change of power grip of affected hand with time (Group 2)

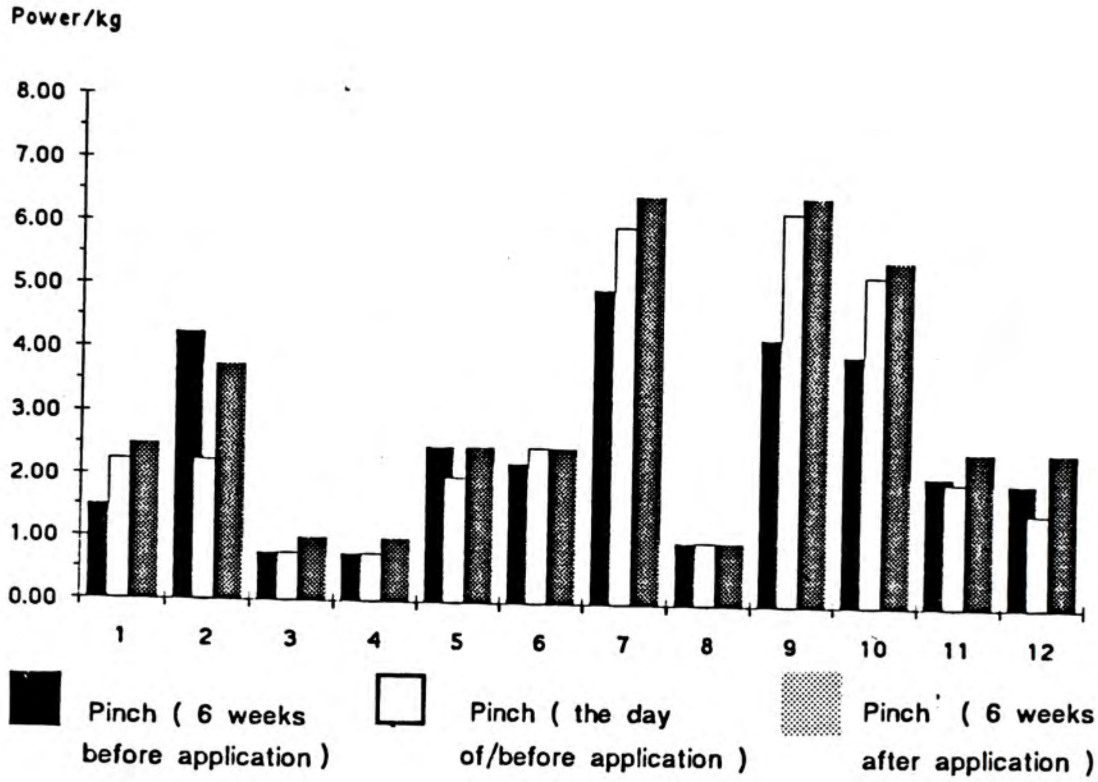


Fig. 8.9 The comparison in pinch grip of affected hand (Group 1)

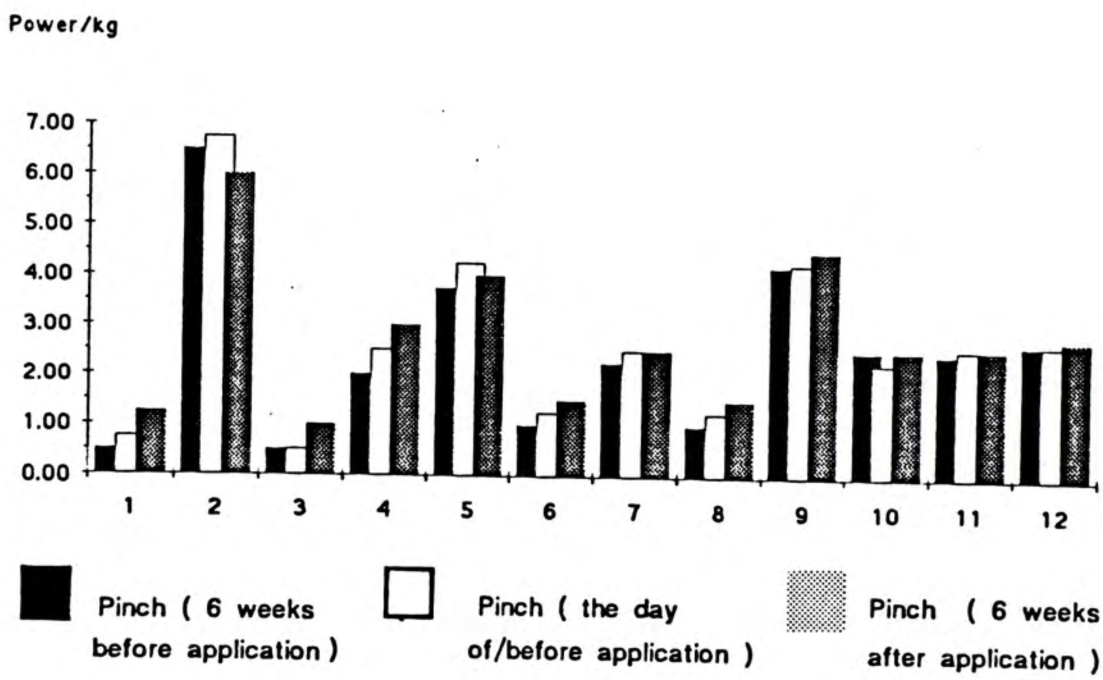


Fig. 8.10 The comparison in pinch grip of affected hand (Group 2)

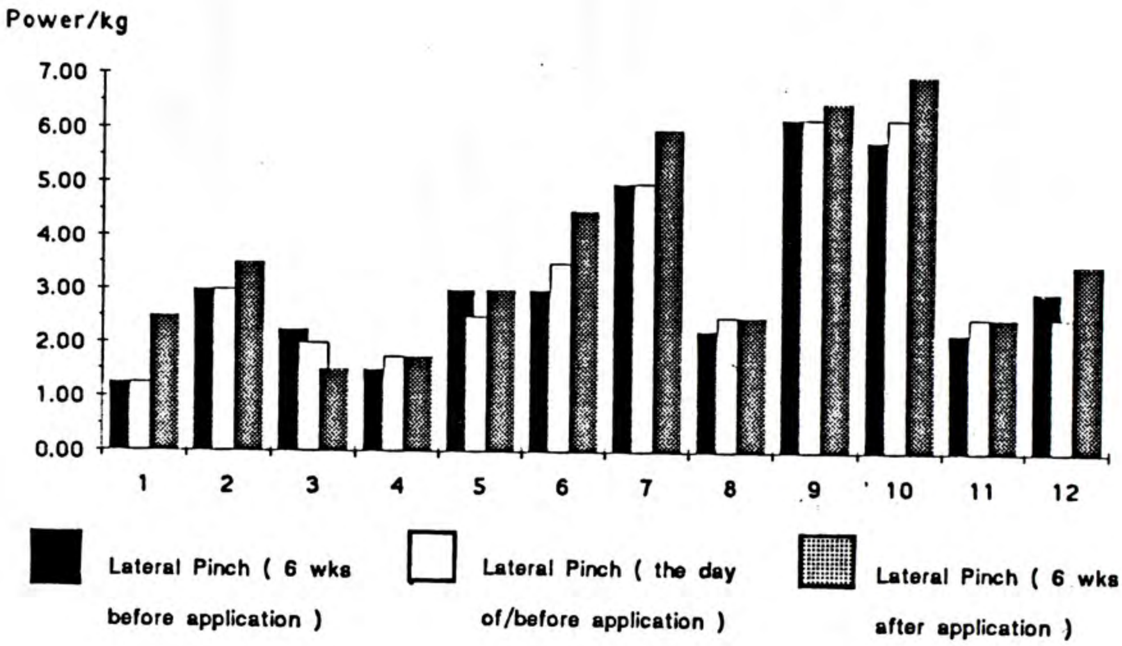


Fig. 8.11 The change of lateral pinch grip of affected hand with time (Group 1)

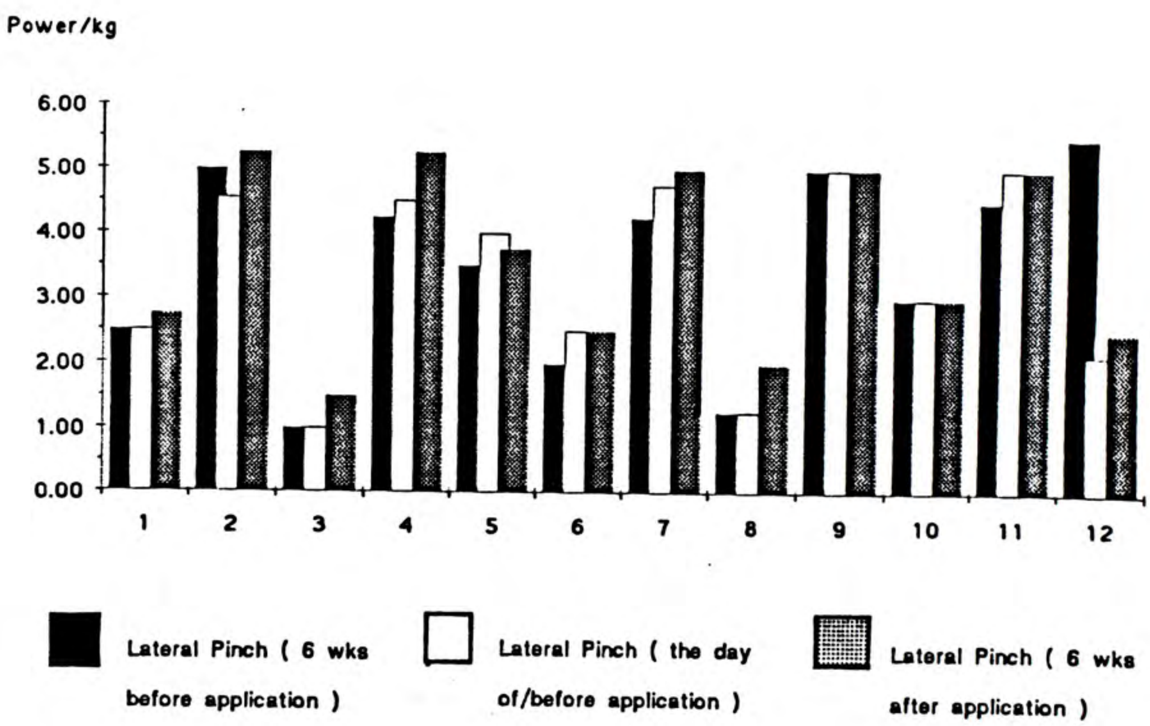


Fig 8.12 The change of lateral pinch grip of affected hand with time (Group 2)

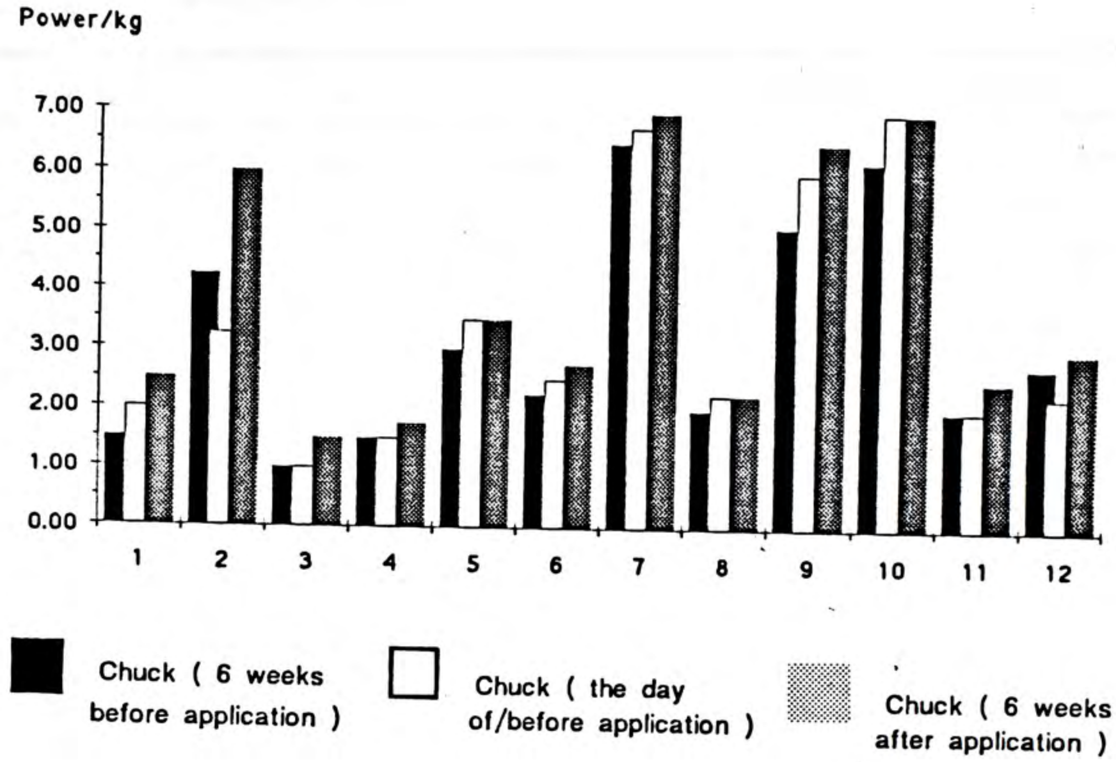


Fig. 8.13 The change of chuck grip of affected hand with time (Group 1)

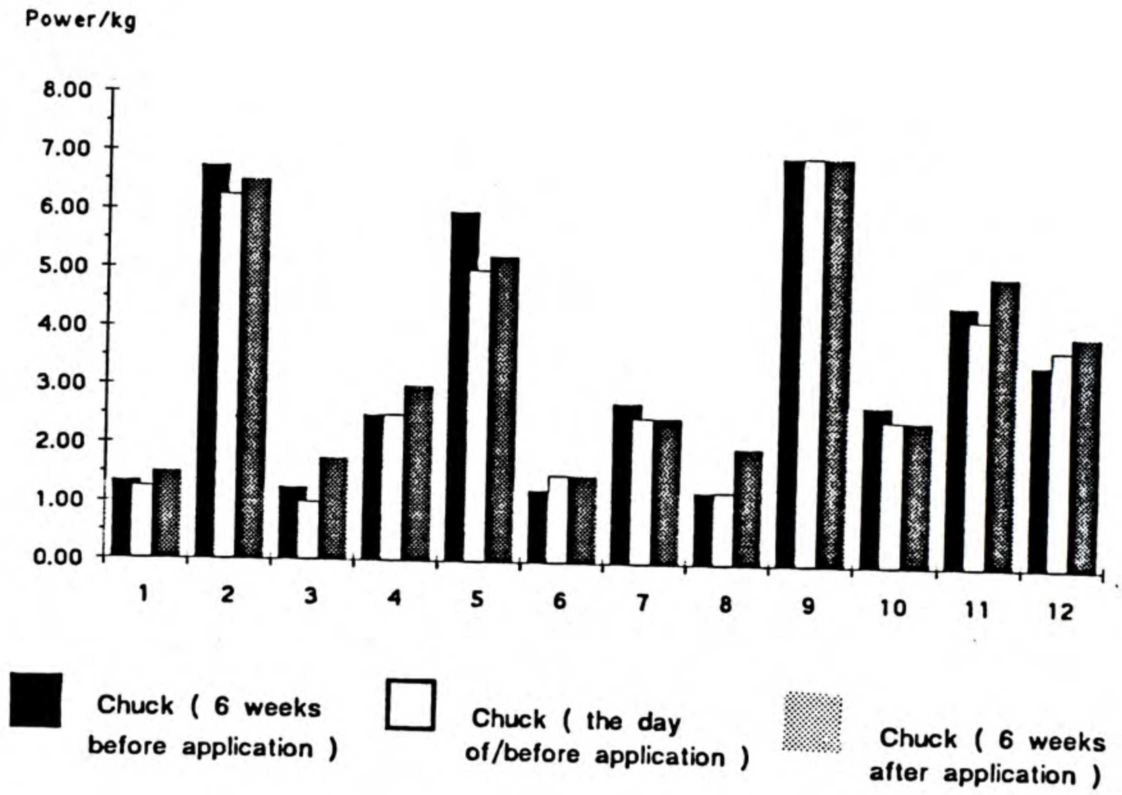


Fig. 8.14 The change of chuck grip of affected hand with time (Group 2)

e. Comparison of Jebsen hand function test score after splint intervention

		Control period		Intervention period		Post splint	
n=12/group	Group	Mean (S.D.)	p-value	Mean (S.D)	p-value	Mean (S.D)	p-value
Total score	one	1.50(3.2)	0.69	7.19(4.3)	0.419	8.72(5.8)	0.168
	two	0.9(4.0)		4.85(3.2)		5.7(4.0)	
Writing	one	0.32(1.8)	0.69	2.47(4.3)	0.419	2.79(4.9)	0.66
	two	0.6(1.8)		1.47(1.5)		2.09(2.1)	
Turning cards	one	0.05(0.6)	0.29	1.15(0.7)	0.151	1.2(0.9)	0.012
	two	0.9(4.0)		0.31(1.0)		0.12(1.0)	
Picking small obj.	one	0.34(0.5)	0.78	1.69(0.4)	0.001	2.03(0.6)	0.001
	two	0.39(0.3)		0.64(0.6)		1.03(0.6)	
Feeding	one	0.57(1.3)	0.76	0.88(0.5)	0.68	1.46(1.5)	0.618
	two	0.43(0.9)		0.75(0.9)		1.18(1.2)	
Stacking chess	one	0.23(0.9)	0.84	0.12(0.68)	0.62	0.35(0.7)	0.85
	two	0.16(0.5)		0.23(0.39)		0.4(0.7)	
Light cans	one	0.1(0.4)	0.61	0.66(0.8)	0.84	0.76(0.8)	0.726
	two	0.28(1.1)		0.62(0.4)		0.89(0.9)	
Heavy cans	one	0.23(0.4)	0.13	0.85(0.8	0.04	0.53(0.6)	0.75
	two	0.32(0.6)		0.24(0.3)		0.46(0.6)	

Table 8.10 Table showing the comparison of the mean differences of the seven Hand Functions Tests before and after splint intervention between group 1 & 2.

There is no significant difference in the overall score of seven subtest. This reflected the complexity of hand functions and a single joint improvement may not reflect the overall improvement of hand functions. However, the result for the picking object subtest and turning card subtest reflected greater improvement in group 1 clients than in group 2 clients. This will be explained in a later chapter in connection with the functional range of motion for these hand functions activities.

f. **Pain Score**

Each client rated her own pain level on the 10 point visual analog scale six weeks before splint intervention, during the period of intervention and six weeks after the programme. The results indicated that there is no significant difference on the three measurements.

n=12/gp	Pain score(I) (mean)		Pain score(II) (mean)		Pain score(III) (mean)	
Group 1	0.17	P=0.62	0.5	P=1.0	0.33	P=0.72
Group 2	0.33		0.5		0.17	

Table 8.11 Table illustrating the mean difference in pain score before and after splint intervention programme

8.2 Summary

8.2.1 The results gathered from the above study have substantiated the following hyptothesis:

(1) Range of Motion

All 24 clients showed significant difference ($p<0.001$)in flexion contracture of affected PIP joint after the splint intervention programme. The results were compared with the control period and was also found to be significant. This implies that the improvement is not due to other medical intervention.

The active flexion of the affected joint has shown significant improvement($p<0.001$) indicating that the joint mobility has improved after splintage intervention.

By comparing group 1 and 2, there is a significant difference in the correction of flexion contracture and active flexion of the affected PIP joint. Group 1 clients with the capener splint showed greater improvement in both aspects. ($p<0.001$ for flexion contracture, $p<0.05$ for active flexion)

(2) Grip strengths

There is a significant improvement in power grip, pinch grip and chuck grip after the splint intervention programme using either the Capener splint or the Belly Gutter splint. There is no significant improvement in lateral pinch grip.

Clients in group 1 showed a more significant improvement in chuck grip ($p=0.004$) than clients in group 2. Although from the statistical analysis, the pinch grip is not significantly different between the groups ($p=0.06$). However, the p-value is approaching the level of significance. Both groups showed similar improvement in power grip and lateral pinch grip.

(3) Jebsen Hand Functions Test

There is a significant difference in the time scores (table 8.7) before and after splint intervention in both groups. This shows that the splint improves hand functions.

Comparing individual subtest of the final score(table 8.10), there is a significant difference in the picking up small object subtest ($p=0.001$) and the turning card subtest ($p=0.012$) between two groups. Clients in group 1 (capener splint) intervention showed a better improvement than clients in group 2. However, in the other five subtests, there is no significant difference between the groups.

(4) Pain Score

Both groups showed no significant difference in pain score before and after the intervention programme.

8.2.2 Compliance and complication of the splint intervention programme

Out of the thirty patients selected for the study, only twenty four patients completed the programme. Four clients suffered from another episode of the exacerbations during the six weeks control period and had to be excluded from the study. One client did not turn up for the second appointment and showed no interest in continuing the splint programme. One client could not tolerate a Belly-gutter splint and dropped out after wearing it for two weeks. Therefore the compliance rate for the Belly

Gutter splint was 92%.

After the splint intervention programme, verbal feedback was obtained from some clients. Most clients in group 2 reported that the belly gutter splint was difficult to apply and remove due to the problem of adjusting the strap. Some clients reported that the splint was not secure enough by the strap and sometimes slipped off from the finger. Other reported that the splint was circular and has poor ventilation. There is often lots of sweat inside the splint.

For those in group one, 75% of the clients reported little discomfort on initial application of the splint. Most clients quickly adapted to the tension of the splint and found the splint useful as a form of exercising the joint during the day. One client (5.1%) complained that the spring wire was rusty after six weeks wear. She was a housewife and probably has a lot more contact of water. Otherwise, there is no complaint on the ventilation or tension of the splint.

Chapter Nine
Discussion

9.1 Introduction

This study aims to investigate the effect of corrective splintage in the management of flexion contracture of the proximal interphalangeal joints of rheumatic arthritic(RA) patients.

In view of the subjectivity of common assessment methods adopted by occupational therapists and patients, there arises the need for developing more sensitive standardised assessment methods for this group of clients. It is also essential to quantify and measure from assessment the effect of therapeutic intervention programme. It is important not only to evaluate objectively the treatment effectiveness but also to improve our professional standard of practice. This study therefore starts by aiming to develop a comprehensive evaluation system on hand functions of rheumatoid arthritic patients.

In the process of study, various splint designs for flexion contracture at the proximal interphalangeal(PIP) joints are studied. The ultimate aim is to analyze mechanically how splint forces are counteracting the soft tissue flexion contracture of the PIP joint.

The major aim of this study is then focused on how two carefully selected types of corrective splints affect the overall hand functions of rheumatoid arthritic clients.

Out of the thirty patients selected for the study, twenty four patients have completed the course of study. From the results of the study, detailed analysis is conducted to highlight how the corrective splints acting on a single joint level (PIP joint) influence the overall hand function of client in terms of active range of motion, grip strengths and functional hand activities of clients. Each aspect of hand function are discussed.

9.2 Comments on the hand evaluation protocol

9.2.1 Reliability and validity of the evaluation system

Reliability refers to the consistency of scores obtained by the same persons when re-examined with the same test on different occasions, or with different sets of equivalent items, or under other variable examining conditions (Anastasi, 1988).

The investigator is aware of the instrumentation reliability for this study. Therefore, before the main study is launched, the instruments including the digital goniometer, the REC grip analyser and the penny giles electrogoniometer are calibrated in the laboratory. Repeated testing has been conducted to ensure the error of measurement to be minimal.

Validity is the most important consideration in test evaluation. The concept of test validity refers to the appropriateness, meaningfulness, and usefulness of the specific inferences made from test scores.

In this study, the investigator had to ensure that:

(1) the methods selected were consistent

(2) the content of the instructions were standardised

(3) the order in which the tests are administered was standardised

(4) the test order for power, pinch, chuck and measurements of JROM were randomised and

(5) the method for recording the data was consistent.

9.2.2 The Hand Evaluation System

As described in previous chapters, hand function should include measurement of grip strengths (Napier, 1956; Skerik, Weiss and Flatt, 1971; Kapandiji, 1970), evaluation of active range of motion, objective hand function tests and activities of daily living (Slack, 1985). In this study, a hand evaluation system is developed including assessment of joint range of motion using digital goniometer, measurement of grip strengths using REC prototype grip analyser, measurement of daily functional activities using Jebsen Hand Function Test.

a. The REC grip analyser

The comparative study conducted previously reflected that the REC grip analyser is more effective and sensitive in the measurement of grip strengths for rheumatoid patients with weak grip strength than the Jamar dynamometers commonly used in clinical settings. In fact, from Fig 6.3 and Fig. 6.4, it clearly shows how the Jamar measurement deviate from the load cell readings(appendix IX). The variation is higher when the measurement range is between 0 to 15 kg. It was shown from table 8.6 that the mean grip strength of the rheumatoid subjects are 11.23 (S.D.=8.2) kg. Some clients have power grip as low as 2.8 kg. This reflects the sensitivity of the REC prototype grip analyzer. If the Jamar dynamometer is used, the recording is therefore inaccurate.

The variation of the readings from the Jymar Dynamometers is mainly due to the lack of appropriate calibration procedures in the clinical settings and the possibility of material fatigue due to prolonged use.

It has been brought to our attention that the sensitivity of the analyser ranges from 0 to 100 kgf with interval of 0.25 kg. In fact, the grip analyser can also be adjusted to maximise the sensitivity to 0.1 kg interval and fabricated like a pinch gauge for measurement of the pinch grip of clients.

b. The Penny & Giles Electro-goniometer

The electrogoniometer was first introduced in the assessment of functional range of motion of lower limbs by our physiotherapy colleagues and the bioengineers at Rehabilitation Engineering Centre. However, it is the first time the goniometer is used to measure joint motion at finger joints during hand functional activities. The G35 goniometer together with the data logger is able to record the changes of flexion/extension at the finger joints during functional activities. The position of the G35 finger goniometer had to be aligned accurately with the axis of joint motions. If the position is displaced sideways, the readings of the joint motion will deviate. Careful positioning of the goniometer is also needed to avoid unnecessary movements that hinder normal hand functions. The goniometer is calibrated so that the flexion angles are in negative values and the extension angles in positive angles as shown in previous chapter. The equipment provides a very accurate analysis on the joint motion during functional activities. In this study, the equipment is used to measure the functional range of motion of both MCP and PIP joints during functional hand activities. The data provides a clear explanation of how the active range of motion of a normal subject differs from a RA subject. It was the initial plan that this equipment would be used as one of the hand evaluation tool for this study. However, it was due to the availability of the equipment that the plan had to be modified. Only the static range of motion are documented for discussion. The equipment can be used for future clinical studies on analysis of active range of motion during daily activities.

c. The digital goniometer

The application of the digital goniometer for measuring the joint range of motion is found more accurate and reliable by minimising human visual error from reading the protractor of the ordinary goniometer. The axis of joint motion is more easily adjusted than the ordinary goniometer and it can be used to measure the hyperextension of joint without repositioning the two arms of the goniometer again.

d. The Jebsen Hand Function Test

The test was translated into Cantonese and was conducted using standardised assessment tools as described by Jebsen (1969). It has been proved for its stability by various authors(Stern,1991, Carlson & Trombly, 1983, Lynch & Bridle, 1989, Hiller, 1992, Hackel, 1992). Although in Hong Kong, the study was conducted on a small scale, the mean difference between the Hong Kong scores and the US scores ranges from 0-15% (dominant hand) and 2.6-15.6% (nondominant hand). There is a greater difference in the mean values over the nondominant hand showing a greater variation on the sample groups in the Hong Kong study and the United States Study. There is also a strong correlation between the Jebsen time score, the X-ray classification and functional class of RA clients ($p < 0.001$ for both dominant hand and non-dominant hand). The results indicate that the Jebsen Hand Function Test is a simple but reliable and valid instrument for measurement of hand functions of the rheumatoid arthritic patients. Moreover, it can provide a comprehensive overall view of clients' hand functions by means of a quick time test. It helps in screening those patients with deterioration of hand functions due to the disease process. The routine X-ray findings and the estimation of functional classification is found less reliable in reflecting patient's actual problems in hand functions. The Jebsen hand function test is a good and reliable tool for occupational therapist to determine the hand functions of clients at various stages of disease processes.

9.3 Discussion of results of the pilot study

9.3.1 Subject Selection

The pilot study conducted in 1992 at Prince of Wales Hospital reflected great difficulties in recruiting suitable clients for the study. It remains difficult to find two rheumatoid arthritic patients with the same clinical presentation and at the same stage of disease processes. Often, there are other associated problems on the same clients and the variations of the clients' conditions are great. For those patients who are at the stage of remission, they do not usually require active medical intervention. They may have low compliance to medical follow up and it is difficult to recruit them into the study. On the other hand, some clients with chronic disabilities often resulting in bony ankylosis or joint destruction which are also not suitable for the study.

Therefore, the investigator began to approach various outpatient clinics (QEH, PWH, QMH) for screening suitable candidates for the main study. It was also suggested that these groups of clients may be recruited by private practitioners. However, as commented in a previous chapter, the soft tissue contracture is often insidious and the patient is not aware of the gradual changes. This leads to the difficulties of collecting subjects for the study, which is not because of its low incidence (Wong, 1990)

9.3.2 Assessment venue and procedures

Most clients were easily distracted from the surrounding treatment areas. There is a need for an assessment corner where the assessment could be conducted more privately. The REC grip analyser and other hand functions assessment required computers and other accessaries. The set up of equipment must be standardised so as to ensure valid assessment each time. The sequence of test must be randomised.

The investigator also found that client showed signs of fatigue after the grip strengths test due to the three trails of measurement. Therefore, in the main study, one measurement is taken for each type of grip measurement. Each client will be given five minute rest prior to the grip strengths assessment. This measurement method has been adopted by Dasari,B(1986) in his study on rheumatoid hand functions.

The assessment of pain has been introduced to identify any significant changes in the pain factor that might influence the outcomes of measurement. Whether the splint is causing any pain or discomfort also would be addressed.

9.3.3 Subject characteristics

Four clients are selected for the pilot study. All clients showed interests towards the splint study and were motivated to improve the deformities. All clients showed good compliance during the twelve weeks of study. Three clients have flexion contracture on middle finger and one on index finger. There may be variations on the measurements of grip strengths. Therefore, in the main study, the distribution of fingers are matched.

9.3.4 Improvement in active range of motion

Two clients in group 1 have a greater improvement on the flexion contracture than those in group 2 (25 degrees vs 12.5 degrees). This initial finding substantiated the mechanical analysis of the two splints that that showed the dynamic splint provided a better gentle, continuous stretching on the flexion contracture than the static belly gutter splint. It would be further analysed in the main study.

The improvement in flexion range in both groups is only within 5 degrees of movement. In fact, one client in group 2 showed deterioration of flexion range after the splint programme. It may be due to the immobilisation effect of the splint on the joint causing limitation in full flexion. It may also be explained by the presence of PIP joint extension contracture due to adhesion of central extensor tendon or articular surface damage during the immobilisation period. The little improvement in active flexion for group 1 clients may be due to active mobilisation of the joint from the splint. However, the clients have to overcome the resistive force of the coil to actively flex the PIP joint. The investigator would like to verify whether the capener splint (I) or the static splint (II) will cause a limitation in flexion range in the main study.

9.3.5 Grip strengths

For measurement of grip strength, there is little difference in power grip, pinch grip and chuck grip between the initial assessment and six weeks after. This indicated that the clients' conditions are quite stable during the course of the study. After the splint intervention programme, group 1 showed a better improvement than group 2 in power grip (0.75 kg difference), pinch grip (0.25 kg difference) and chuck grip (0.625 kg difference) but the mean difference is minimal. It was expected that in the main study, the pinch grip should improve in group 1 as the capener splint is providing a strengthening component (active resistive flexion) to the finger flexors. Further investigation has to be done on the effect of the splint in grip strengths.

9.3.6 The Jebsen Hand Function test

The mean difference between the initial and the presplint assessment is minimal among the four clients(0.94 sec) showing that the conditions of RA clients are quite consistent during the six weeks control period despite of regular medication or other treatment.

However, there is a greater difference after the splint intervention programme in both groups. Group 1 shows a greater difference that group 2 indicating that the dexterity of group 1 clients is better. This may be explained by the fact that the capener splint allows more active flexion and extension of finger joints allowing the joints to be more mobile and the dexterity skills was thus improved. This needs further investigation.

9.3.7 Discussion on the functional range of motion

The Penny & Giles Finger Electrogoniometer has been used for a comparative review of a normal subject and a rheumatoid arthritic patient. The results are discussed briefly in chapter six. It shows that the MCP joint of a rheumatoid finger tends to hyperextend to compensate for the loss of PIP extension during the activities. This finding is substantiated by Swanson(1986) and is reflected from the graph in fig. 6.13 and fig. 6.14. The RA subject tends to hyperextend the MCP joint to about 5-10 degrees when performing the card turning test and the picking up light and heavy cans test. This can also help to explain the pathology of the boutonniere deformity on RA fingers.

Further more, it showed that during most hand functional activities, the proximal interphalangeal (PIP) joint moves from 20 to 60 degrees (fig. 6.1) and the MCPjoint from 10-80 degrees for a normal person. Although this has little inference to the normal population since one subject is observed, this would serve as a reference for the main study.

Although this study cannot make a conclusive statement regarding the functional range of motion due to the limited number of clients, it arouses insights for further indepth analysis of the joint motion at a dynamic activity as described by Landsmeer, Bendz on description of hand function.

9.4 Discussion of the results from the main study

9.4.1 Subject selection

30 subjects are selected initially for the study. Six clients had another episode of arthritis during the course of study and therefore withdrew from the study. The remaining 24 subjects were matched according to age, hand dominance, hand involvement and were divided into the two groups for comparison. All patients are requested to sign the consent form (appendix VII) and agreed to comply with the twelve weeks treatment protocol.

The age ranged from 16 to 73. There are 2 clients aged beyond 55 years of age selected for the study. This is mainly due to the difficulties in recruiting suitable candidates for the study.

Among the occupation, there are housewives (45.8%), clerk (25%), student (16.7%), factory workers (4,2%), tailor (4.2%) and teacher(4.2%). This may represent the common work distribution for the RA clients. All clients are right hand dominant, thus minimising the effect of hand dominance on the Jebsen hand function test score.

As shown from previous studies, various factors including occupation, age, sex and hand dominance (Thorngren & Werner (1979), Schmidt & Toews (1970), Hackel et al(1992) influence the hand functions of clients. In view of this, the investigator attempted to design the research study by a matched pair criteria to minimise these factors influencing the outcomes of measurements (table 8.2.4).

9.4.2 Effect of splint on flexion contracture of the PIP joint

Both groups (group 1&2) of subjects showed no significant difference in the initial score(6 weeks before) and the score before splint application. This indicated that the subjects' conditions are quite stable and that any changes later is due to the effect of the splint intervention. After the splint intervention, improvements in the correction of flexion contracture at the affected PIP joint are observed ($p<0.001$). This was clearly reflected by comparing the 24 subjects between the control period(6 weeks) and the splint intervention period(6 weeks). This also indicates that the improvements are not due to medications or any forms of continual therapy. The disease process is also accounted for by comparing the pain score before and after intervention of splints.

By comparing the mean differences between group 1 and 2 before and after intervention of splints using t-test, subjects in group 1 demonstrated better results than subjects in group 2.

This finding is substantiated by the mechanical analysis of the two splints as described in chapter four. The force generated by the dynamic finger extension splint(capener splint) is proportional to the deflection angle of the joint. The bilateral coil at both sides of the PIP joints helps to provide the continuous torque force to extend the finger. The force could be adjusted (by modifying the dimensions of the coil) to provide the best stretching force tolerable by the patient. While the traction of the static belly gutter splint is deteriorated when the flexion contracture decreases.

According to some feedback from the subjects, the dynamic splint was easy to apply and remove. It was also very handy. It also facilitated the clients to put on the splint more regularly in between daily activities. Whereas the static splint has to be adjusted every time when the splint was applied with the velcro strap across the joint. The amount of the forces generated varied from each application according to the tension of the strap. Clients therefore found difficulties in adjusting to the right tension of the strap.

9.4.3 Effect of corrective splintage on active flexion of the proximal interphalangeal joint

It was interesting to find out that the active flexion of the PIP joint has improved when the flexion contracture of the joint has been corrected. The explanation is that there is soft tissue contracture at the joint causing PIP joint extension contracture. As a result, the active flexion is limited. The causes of extension contracture may be due to adhesion of the central extensor tendon, articular surface damage or damage at the volar plate in particular would be responsible for this motion(Strickland, 1985). He also mentioned that active mobilisation of the joint is favourable to correct the contracture. From this study, group 1 clients showed a better improvement than group 2 clients. This may be explained by the fact that the Capener splint encouraged both active flexion and extension during the splint programme whereas the static splint did not. Therefore, it is concluded that the splint would not only limit the active flexion of the joint but at the same time provide active mobilisation in both flexion and extension. It is also noted that although improvement is seen, it is not as significant as in active extension since the splint force is providing traction against the flexion contracture and not the extension contracture. For clients in group 2, the result showed that there are some improvement in the active flexion. This can be explained by the fact that all clients are encouraged to mobilise the joint during the day when the splint is removed.

9.4.4 Effect of corrective splintage on the grip strengths of hand

From the results as reflected in both groups of clients, there are significant difference in grip strengths after the splint intervention programme. This may be explained by the fact that the flexion contracture may have direct influence on the grip strength of clients. The soft tissue contracture may be due to shortening of collateral ligaments or other factors as described previously. Once the contracture has developed, the finger has adapted to a faulty position of grip. The flexor tendons and the extensor tendon excursion have changed and the mechanical advantage has decreased. Thus, the grip strengths is affected. Once the soft tissues contracture have been dealt with, the tendon excursion is working at its best mechanical advantageous position. Therefore, the grip strength improved.

The investigator is expected to see a better improvement in grip strengths from group 1 as the dynamic finger extension splint has a strengthening effect on the flexor groups of muscles by countering the coil resistance. However, only the chuck grip is found significantly different between the two groups. This may be explained by the fact that the coil resistance may not be strong enough to resist the active flexion of the finger as a strengthening component. It was very important to monitor the coil stiffness in rheumatoid arthritic patients because too much resistance would arouse pain and discomfort. Too little resistance would affect the corrective force on the flexion contracture. Clients in group 2 did not show a significant deterioration of grip strengths after the splint intervention. This is also substantiated by Stryker(1979) who commented that immobilisation splint would not interfere with grip strengths of clients provided that the period of immobilisation is not very long.

9.4.5 Effect of corrective splintage in Jebsen Hand Function test

The result reflected that once the flexion contracture is corrected, there is a significant improvement in the hand dexterity during hand functional activities. This was shown by comparing the two groups pre and post splint intervention. Both groups showed significant results in the time score. Even one single joint out of the 14 joints on the hand would interfere with the outcomes of hand function. This is reflected in the study.

By comparing the two types of splints, it was shown that not all the subjects showed significant difference. Only the pick up test and card turning test are significant($p<0.05$). This can be explained by the fact that these two subtests involve more PIP joint motion as substantiated by the electrogoniometry study. If splint 1 has greater improvement in flexion contracture and active flexion of the PIP joint, the hand function would consequently be improved. For other subtests, as it may involve more on the other finger joints or wrist joints, the effect is not significant. This result definitely stimulate the therapist to further analyse in depth the functional range of motion of various joints during daily activities. A standardised hand function test should incorporate this concept of functional range of motion into the test procedures.

9.5 Implication of the study for occupational therapy practice

Occupational therapists are often involved in the assessment and treatment of rheumatoid arthritic patients. Splinting programmes are often introduced as a modality of treatment. In the past, therapists have often been very conservative in prescribing corrective splintage for this group of clients. Often, only resting paddle splints or working wrist support splint are prescribed aiming at relief of pain and prevention of deformities.

This study reflects the effectiveness of corrective splintage in the management of flexion contracture of a arthritic joint. Dynamic splintage is proved to be more effective in correcting the soft tissue flexion contracture at the PIP joint in terms of active range of motion and hand functions performance.

However, therapists have to be very careful in monitoring the resistive corrective force. Both objective measurements in terms of defining the coil strengths and subjective feelings of clients should be taken into consideration.

One has to be very careful not to correct fixed deformities or any joints that are severely destroyed due to the disease.

On the other hand, the study has developed a very comprehensive evaluation system on the rheumatoid hand including measurement of grip strengths, active range of motion and hand functions using standardised hand functions test. This should serve as an assessment protocol for future practice.

Moreover, this is apparently the first clinical study conducted by an occupational therapist on rheumatoid arthritic patients locally. Although this may not be a perfect research, it is hoped that practising therapists would have their research interest aroused enough to develop ongoing clinical studies on other patients in the field.

9.6 Limitation of the study

No two rheumatoid arthritic patients present the same clinical pictures and degree of disability. In this clinical study, the investigator tried to use the same client to compare the clinical effectiveness of splint intervention instead of developing a control group. However, in matching the two groups of clients for comparison of static and dynamic finger extension splint, the investigator could at most match according to age, sex, year of onset and functional class. The degree of deformity for each individual hand varies a lot. It is almost impossible to recruit clients with solely flexion contracture on one finger joint. However, the investigator was careful not select those clients with severe thumb or wrist deformities as it in fact would affect the outcomes of hand function assessment.

In view of the screening difficulties, the investigator only recruited 24 clients for the clinical study (initial plan n=30 clients). This may explain why some findings are not significantly different. The number of subjects may be too small to generalise a statement of validity.

Although standard procedures have been adopted for assessment of clients, there may be examiner bias. Therefore, the investigator is very careful not to provide verbal cues or encouragement to all clients. Human errors in alignment of joint axis, reaction time for stopwatch tests may exist. The effect is hopefully minimised by using the same examiner throughout the study.

The fabrication procedures for both splints have been standardised. However, the investigator often used clinical judgement to adjust the splint. Subjective feedback of clients on the splint is of major concern. Rapport is also important between investigator and the clients to facilitate good compliance of the programme.

Professional ethics have to be accounted for by the investigator. Other modalities of occupational therapy intervention would be given if deemed necessary. The investigator is also very cautious to avoid overlap of any other direct treatment on the same hand. Clients are reminded not to wear any hand splint other than the prescribed splint during the study.

Only two subjects are involved in the electrogoniometer study due to the technical problems in sharing the goniometer. On the other hand, the laboratory is too far away for our rheumatoid arthritic clients to travel to. No conclusive statement can be made from that part of the study. However, this observation provides an initial framework of motion analysis on the hand and fingers in future.

The study involved the uses of FSR in measurement of the force generated by the two splints acting on the fingers. There are limitations in gathering enough clients for a proper study. Yet, the initial findings may hopefully stimulate researchers to look into this problem.

More extensive research could also be conducted on the standardisation of the Jebsen Hand Function test and the collection of a norm in local chinese population. The test can be further analysed by using the Penny and Giles Goniometer to investigate the functional range of motion of various finger joints in carrying out the seven subtests and their inter-relations.

9.7 Summary

This study aims at developing a comprehensive evaluation system for rheumatoid arthritic patients. By using this objective standardised protocol, the investigator aims to compare the effect of two corrective splints on the overall hand function of patients. One of the objectives is to study whether the dynamic finger extension splint (capener splint) is more effective than the static belly gutter splint in improving the hand function of the rheumatoid arthritic patients.

Results indicated that both corrective splints showed significant difference in the correction of flexion contracture of the PIP joint six weeks after the intervention programme. The grip strength are also improved after splint intervention. The hand function as measured by the Jebsen Hand Function

Test have improved.

The capener splint is more effective than the static belly gutter splint in the correction of flexion contracture at the PIP joint. The dynamic splint also has exerted effect on the grip strengths of the clients in terms of power grip, pinch grip and chuck grip. Both splints show similar results in the hand function test except that in the pick up small object test, group 1 clients have better performance.

This shows that corrective splintage is effective in improving the hand function of rheumatoid arthritic patients with flexion contracture at the proximal interphalangeal joint. However, the dynamic splint generating prolonged gentle stretch is proven to be more effective than the strong passive stretch generated by the static belly gutter splint. The position of application of corrective force, the torque generated at the PIP joint causing joint compression, the contact pressure, the cosmesis and the handy characteristics of the splint designs are the key factors to consider in the management of flexion contracture for rheumatoid arthritic patients.

Chapter Ten
Conclusion and Recommendations

10.1 Conclusion

This study aims at comparing the effect of corrective splintage on flexion contracture of rheumatoid fingers. Twenty four rheumatoid arthritic(RA) patients are selected carefully for the study. Two types of corrective splints, one static (belly gutter splint) and one dynamic (capener splint) are selected for comparison of their effectiveness.

Before the conduction of the main study, a comprehensive hand evaluation system has been developed as an objective assessment to compare the splint effect on hand function. The hand evaluation system include measurement of maximum active range of motion, grip strengths, dexterity and pain. Several common assessment tools are chosen for comparison of their reliability and validity. However, from the experimental studies, the Jamar dynamometer which is commonly used by clinicians, was found to have very poor reliability and variability among different instruments. The variation is not on a linear scale. The discrepancy is high in measurement of weak grip (less than 10 kg.) On the contrary, the REC prototype grip analyser is found to be a more reliable measurement tool for grip strength. Therefore, in this study, the grip analyser is chosen for measurement of hand grip for our RA clients. In measuring the joint range of motion, finger goniometers are commonly used in clinical practice. It was found that there is a high reading error from the goniometer. The mini-digital goniometer is chosen for this study in measuring the finger motion since the digital display can minimise the human error on readings. However, the axis of the goniometer still has to be placed exactly over the joint axis.

In view of the lack of any standardised hand function assessment for our RA clients in Hong Kong, a preliminary study was conducted to develop this equipment. The Jebsen Taylor hand function test was selected for this study. Results indicated that the test is a reliable assessment tool in for measuring hand functions. The mean scores of RA clients are higher than the normal subjects. There is a significant difference in the time score among different functional classes or X-ray classification as illustrated by using the Kruskal-Wallis ANOVA test (0.0003 for dominant hand and 0.005 for non-dominant hand). This further substantiates the validity of the Jebsen Hand Function test in measuring hand function of RA clients. By adopting the above evaluation system, the main study was conducted. All subjects were assessed initially on the active range of motion, grip strength, hand function assessment and pain measurements. After six weeks interval, a re-assessment was conducted. Then they were divided into two groups incorporating two different splint programmes. Six weeks later, a post splint assessment was conducted again.

All clients showed significant improvement in their hand function after the splint programme. This indicated the effectiveness of corrective splintage on the correction of flexion contracture of the joint, improvement of grip strengths and the improvement of hand dexterity. Although one single PIP joint received intervention with the splint programme, this still can reflect the significant implication of how a joint would interfere with the function of the whole hand. The findings of this study were based on only twenty four subjects, hence careful interpretation of the results is needed and future work is required to substantiate the present findings.

When comparing the effect of the static belly gutter splint and the dynamic capener splint, there is significant difference in the correction of flexion contracture on the PIP joint. Group 1 showed a better result than group 2 ($p<0.001$) from this one may concluded that the dynamic splint with a constant stretching force provided by the spring coil is more effective in the correction of flexion contracture of the PIP joint than the static splint. Considering the limitation of active flexion of the joint after the splint programme, there is no significant deterioration of active flexion post splint. In fact, there is a significant improvement after the splint programme($p<0.001$). Group 1 showed a better improvement than group 2. From this one may conclude that the dynamic capener splint which provide a movable coil in flexion and extension of joint is more effective in increasing active flexion.

There is no significant difference in grip strengths of both groups showing that both splints did not exert any effect on improvement of grip strengths. The belly gutter splint which has long immobilisation period during splint wearing did not reflect a decrease of grip strength. One can therefore conclude that intermittent immobilisation did not affect the grip strength. The capener splint encouraged clients to actively flex and extend during splint programme. Clients have to overcome the coil resistive force to flex the finger, thus strengthening the flexors during the splint programme. As a result, the clients in group 1 had a better improvement in chuck grip ($p>0.05$) and pinch grip ($p>0.06$). One can conclude that the dynamic capener splint is more effective for improving the pinch and chuck grip of the affected hand.

For the Jebsen Hand Function test, there is no significant difference when comparing the two groups showing that both splints may have similar effect on dexterity. However, in the card turning and picking up small objects subtest, those clients with dynamic splint programme showed a more significant improvement than the static splint group($p>0.05$). One can conclude that the dynamic splint effects an improvement in dexterity of the finger since both tests are more specific to the finger movements while the other subtests involve other finger joints and wrist motion.

There is no significant difference in pain score before and after splint application. This demonstrates that corrective splintage would not cause pain over the contracted joint as long as the amount of corrective force provided is carefully monitored.

Occupational therapists in the past are quite reserved in prescription of corrective splintage for RA patients. They are worried about the compliance and pain factor. From this study, one can see that if the amount of corrective force is carefully monitored, PIP finger extension splint is effective in improvement of hand function of clients even though only a single joint is affected. It also suggests that early intervention is indicated. If the splint is applied when there is already joint or bone destruction, the effect will be insignificant.

The dynamic capener splint with constant coil resistive force to counteract the flexion force of soft tissues are more effective in correction of flexion contracture. The pinch grip and chuck grip could also be improved by strengthening of the flexors during the splint programme. The dexterity skill of the hand could be improved.

This research has served to develop a simple experimental study for use in investigating treatment effectiveness of a particular programme. Information gained from this study has helped to develop further research among the occupational therapy practitioners in Hong Kong. The investigator hopes to share the information obtained from the study among all therapists working with RA patients in the local scene.

10.2 Recommendation

Traditionally, occupational therapists gathered subjective feedback from RA clients on their progress throughout therapy. Objective assessments are usually confined to measurement of joint range of motion and grip strengths without looking into the total perspective of hand function. This study attempts to develop a comprehensive evaluation system on RA hand function beyond the subjective feedback from clients. Therapists are advised to conduct objective evaluation to monitor the progress of clients and the responses to therapy.

a. Based on the outcomes of the study, it is also advised that corrective splintage should be prescribed when a soft tissue contracture has developed at the joint causing limitation of joint motion, thus hindering hand functions. Early intervention is recommended to prevent the contracture developing into permanent deformity.

b. Patients compliance is also very important in any splint programme. Simple splints easily applied and removed are welcome by patients. In the humid weather of Hong Kong, good ventilation should also be considered in the design of splints.

c. Dynamic splint is more effective than static splints in the correction of soft tissue contracture by providing a steady traction force to counteract the contracture. However, care should be taken not to overstretch the delicate tissues around the inflamed RA joint. Coils should be standardised and graded with resistance.

d. For RA patients, it is reasonable to suggest that in the measurement of grip strengths, only one trial should be taken to avoid overstraining. Since their grip strength is usually weak, more sensitive device should be used for measurement.

e. Standardised assessment procedures should be adopted for each assessment. The Jebsen Taylor Hand Function test is recommended for measurement of the hand functions of RA clients.

f. The pain factor is very important in the management of RA patients. It is often the first indication of deterioration due to disease. This should be considered an important part of assessment.

10.3 Suggestions for further research

Further studies to investigate the effect of splintage on the various deformities in RA clients should be encouraged. The biomechanical analysis on different designs should be conducted. Further indepth analysis of hand function of the rheumatoid population would be very interesting. Experimental design in the study could be adopted for other clinical studies which compare the effectiveness of therapy without interfering with other medical treatment. The evaluation system can further be developed and test on its inter or intra rater reliability. The use of the REC prototype grip analyser as a clinical tool can be adopted for grip measurements for other hand injured clients but local norms have to be obtained. The Penny and Giles electrogoniometer is considered to be a very sensitive equipment in the measurement of active functional range of motion during daily activities. Further studies in this area are suggested.

APPENDIX I

I. Criteria for the diagnosis of rheumatoid arthritis

The American Rheumatism Association (ARA) (1958-revised) has classified the various forms of disease as classical, definite, or possible, depending on the number of characteristic features present as follows:

1. Morning stiffness
2. Pain on motion or tenderness in at least one joint
3. Swelling (soft tissue thickening or fluid, not bony overgrowth alone) in at least one joint
4. Swelling of one other joint
5. Symmetrical joint swelling with simultaneous involvement of the same joint on both sides of the body
6. Subcutaneous nodules over bony prominence, on extensor surfaces, or in juxta-articular regions
7. Radiological changes of Rheumatoid arthritis(which must include at least bony decalcification localised to or greatest around the involved joints and not just degenerative changes)
8. Positive agglutination (anti-gamma globulin) test (demonstration of "Rheumatoid factor")
9. Poor mucin precipitate from synovial fluid (with shreds and cloudy solution)
10. Characteristic histologic changes in synovial membrane
11. Characteristic histologic changes in nodules

Categories	No. of criteria	Duration of symptoms
Classic	7 of 11	6 weeks
Definite	5 of 11	6 weeks
Probable	3 of 11	6 weeks

APPENDIX II

Assessment for Rheumatoid Arthritis

Name: ______________________ Sex/Age: ______ Centre/Code No.: _________

Onset of RA: __________________ Onset of Deformities: ____________________

Surgery to Hand: ____

Data obtained from: Direct Assessment / Previous Record

	Right Hand					Left Hand				
FINGER	T	I	M	R	L	T	I	M	R	T
DIPJ										
PIPJ										
MCPJ										
WRIST	FLEX:		EXT.:			FLEX:		EXT.:		
	UD / RD :					UD / RD :				
MCPJ (M/F)	UD / RD :					UD / RD :				

NOTE : To Assess the hand in its relaxed position.

Fill in the space with the following codes:

O	:	in neutral position (OS - when the joint is stiff)
F	:	in flexion position
H	:	in hyperextension position
UD	:	in ulnar deviation
RD	:	in radial deviation

Signature ____________________

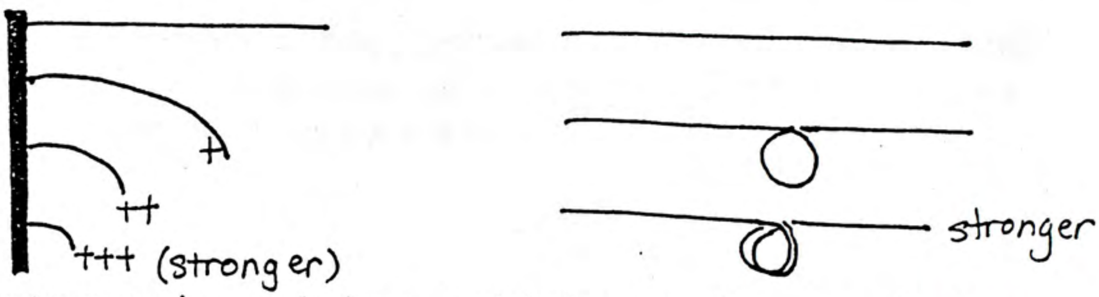
Date ____________________

APPENDIX III

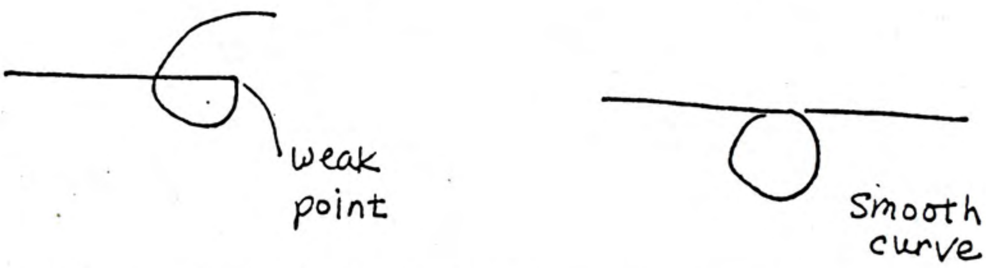
Guidelines for fabrication of spring coil

A. Basic principles in coil fabrication:

1. The longer the wire, the less powerful will be the resistance to a force at the end of the long lever arm.

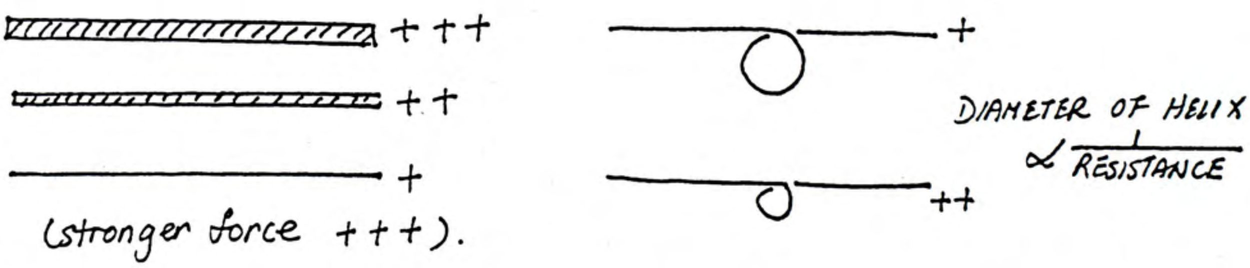


2. A diameter extension producing a semicircle on the first turn will allow the coil to be position at the axis of the joint. However, it may create a weak point if the coil is bent more than 90 degrees.

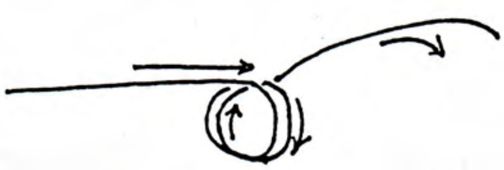


3. By incorporating the helical twists, the required tension of the coil can be adjusted.

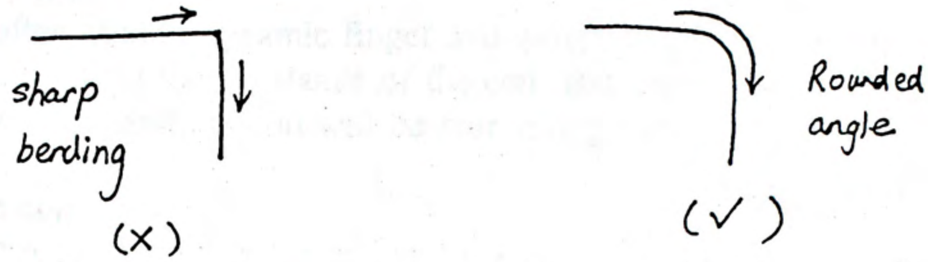
4. The calibre of the wire, its length and the diameter of the helices are the three factors which must be calculated to fit the tension of the spring.



5. Force applied to lever arm will follow the direction of the last helix



6. When bending the wire, right angles or acute angles should always be rounded to avoid snapping in use. Round-nose pliers are useful at this stage.



7. The axis of the helix should approximate to the axis of movement of the joint to be motivated, thus the arc of movement of the external lever continues parallel to that of the segment.

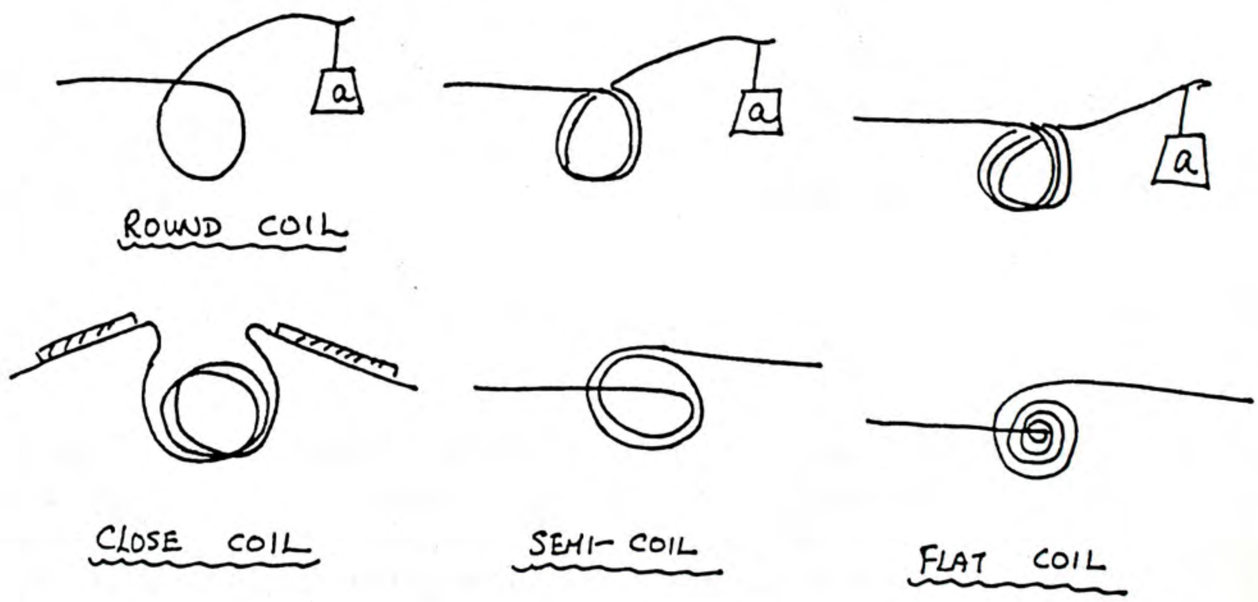
B. Types of spring coils

1. Round coil
It is often used in dynamic finger and wrist splints. The number of turns does not affect the resistance of the coil. But the rotational stiffness will be increased and the coil will be mor springy and more durable.

2. Close coil
The direction of force for this coil is directed to the helix of the coil and there is a tendency to open the coil. It is less commonly used in local clinical settings but is available commercially. This coil will allow better alignment of the joint axis at both sides.

3. The semi-coil
It is often fabricated by local therapists using commercially available T-shape spring coil turning device. It is easier to align one of the joint axis as it directs to the centre of the coil. But therapist has to be aware of the material weakness at the sharp turn to form the semi circle. This may decrease the springy property of the spring wire.

4. The flat coil
It is also fabricated commercially but not in local occupational therapy units. The advantage of using the flat coil is that eventhough the number of turns of coil has increased, the thickness of the coil will remain the same. It is recommended for use on finger splint (eg. capener splint) where there is a narrow web space in between.



References

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Appendix IV

Measurement of forces of corrective splintage using FSR

Introduction

In the analysis of joint forces acting on the fingers by the corrective splintage, there arises the questions of measurements. Often free body diagram indicated the direction and magnitude of forces, but was unable to reflect the actual amount of forces the splint is acting on the fingers.

In view of this, a laboratory study has been conducted aiming at measuring the actual amount of forces generated at different part of finger by the splints. Two splints: the belly gutter splint and the capener splint are chosen for the study to compare the corrective force. A Force Sensing Resistor (FSR) is used for the measurement of the applied force.

The Force Sensing Resistor(FSR)

The FSR were constructed using a modified commercially available conductive polymer pressure sensing element. These sensing elements are composed of two conducting interdigitated patterns deposited on a thermoplastic sheet facing against another sheet containing a conductive polyetherimide film (see attached diagram). A spacer placed between the tow plastic layers has a cutout that permits the two sheets to make electrical contact when pressure is applied but otherwise cause the sensor to have infinite impedance in the unloaded state. As applied pressure increases, the two layers compress together increasing the contact area. This subsequently decreases the electrical resistance and creates a shunt between the interdigitated patterns(Mokshagundam, 1988). An epoxy dome is placed over the sensing area to direct all of the applied force through the effective sensing area (12mm) to measure force instead of pressure. The completed sensor was only 1.8mm thick and capable of being taped to the finger pads for measurement.

Calibration of the sensor

Each force sensor was calibrated individually against the loading machine as shown in the following diagram. Calibration force range are preset at the loading machine in connection with the oscilloscope. The loading force is measured in line with the output voltage from the oscilloscope. The data is then transformed into the graphical plot with the loading and unloading curve drawn as below. The test is repeated again. The calibration curve is thus obtained for comparison.

Methodology

The FSR after calibration is then mounted onto the different parts of the fingers as shown below:

a. Belly gutter splint (at dorsum of the PIP joint under the strap)
b. Capener splint (at the MCP, PIP and DIP level)

and connected to the oscilloscope for measurement of the voltage difference when the splint is applied onto the finger. The test is repeated twice to compare the amount of forces generated. For the capener splint, two position of motion is measured, one when finger extension and when finger is flexed.
Three subjects are selected for the study (one normal subject and two RA subject with flexion contracture 35,45 degrees respectively) to compare the force generated by the splint.

Results

The following table illustrate the distribution of forces over different splint parts:

Subject 1: RA patient with flexion contracture 25 degrees at PIP joint
Subject 2: RA patient with flexion contracture 35 degrees at PIP joint

<u>Capener splint</u>

a. PIP joint in extension

Subject	MP position		PIP position		DIP position	
	Volt. (V)	Force (N)	Volt. (V)	Force (N)	Volt. (V)	Force (N)
RA(1)	0.3	2.5	0.7	9	0.3	2.5
RA(2)	0.1	2	1.0	10	0.4	4
Normal	0	0	0	0	0	0

b. PIP joint in flexion

Subject	MP position		PIP position		DIP position	
	Volt. (V)	Force (N)	Volt. (V)	Force (N)	Volt. (V)	Force (N)
RA(1)	0.9	9	0.1	2	1.35	11
RA(2)	0.2	2	0	0	1.65	21
Normal	0.2	2	0	0	1.85	25

b. Belly gutter splint

Subject	MP position		PIP position		DIP position	
	Volt. (V)	Force (N)	Volt. (V)	Force (N)	Volt. (V)	Force (N)
RA(1)	--	--	1.35	18	---	--
RA(2)	--	--	1.9	38	---	--
Normal	--	--	0.3	2	---	--

The result showed that the corrective force generated at the dorsum of the PIP joint by the belly gutter splint is very high (range from 18 to 38 N). With such a small surface area of contact, this will increase the pressure exerted onto the skin. Due to difficulties of applying the sensor to the concave surface of the splint, only the measurement at the PIP position was taken.

For the capener splint, there is a even distribution of corrective force at the MCP and DIP position. However, the PIP position still share the highest loading of force to compensate the flexion contracture of the joint. When the finger is flexed, the force at the PIP joint is lowered and at the DIP position, the force is high. This is counteracted by the force generated by the long flexors of finger to resist the stiffness of the coil.

Conclusion

This is a small technical investigation with an attempt to measure the amount of corrective force generated by two types of splints in its effort to counteract the flexion contracture over the joint. It is also the first time a FSR is used to measure force at the finger joint.

The data reflected that the greater the angle of flexion contracture, a higher amount of corrective force is generated to counteract the contracture.

The belly gutter splint exerted maximum force over the dorsum of the PIP joint which may cause pain and discomfort on prolong wear.

For the capener splint, the highest point of force is at the dorsal proximal phalanx but by comparing with the belly gutter splint, it is relatively lower. Because the sample of subjects is small, the result is only used as a reference. Further study is recommended before any conclusion can be drawn.

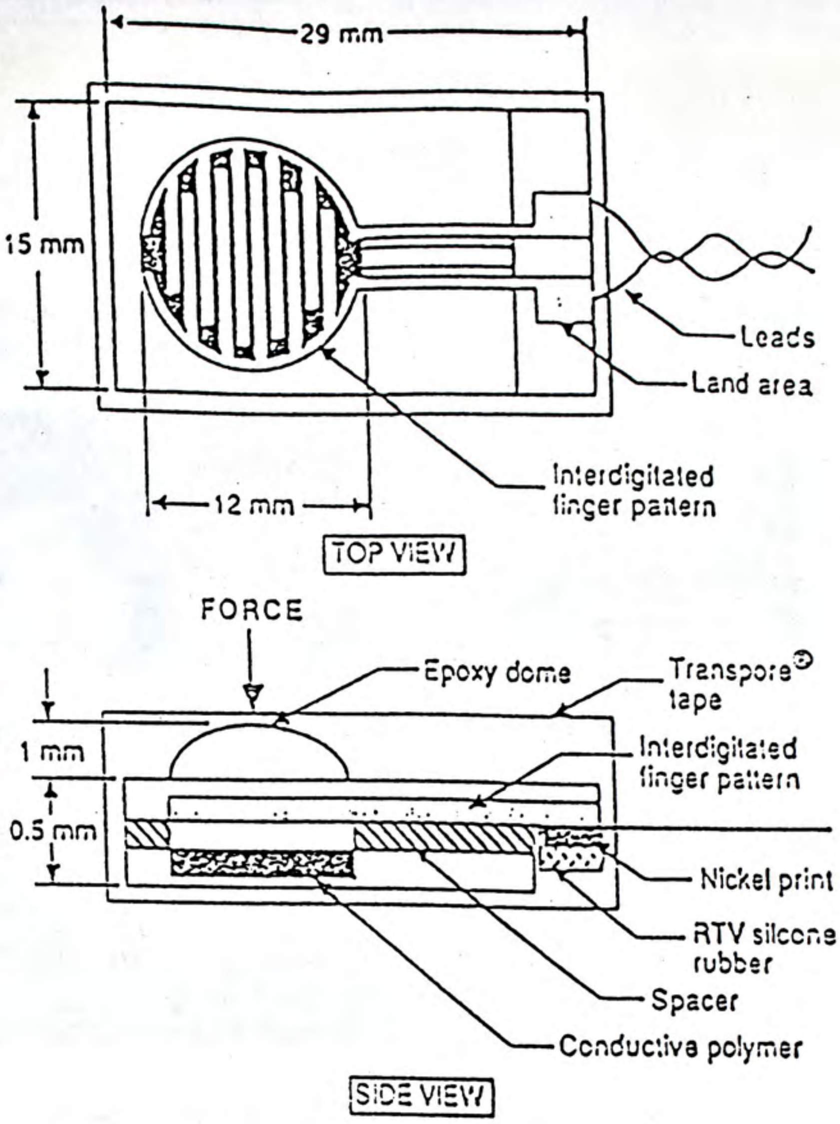

Fig. 1. Schematic diagram of the conductive polymer finger force sensor showing top and side views. After a dome was placed over the conductive polymer sensing area the sensor was encased in Transpore[5] tape.

Fig. 2 The FSR attached to the base of the distal phalanx using tape

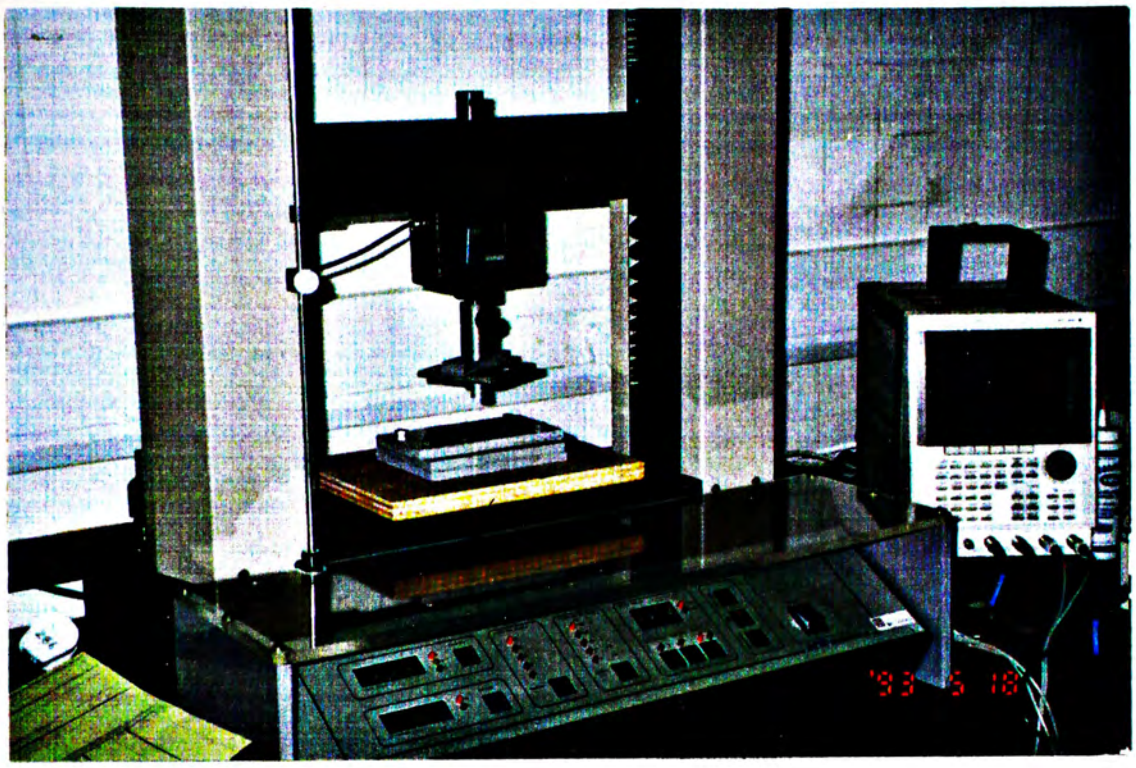

Fig.3 The Loading machine for calibration of the FSR

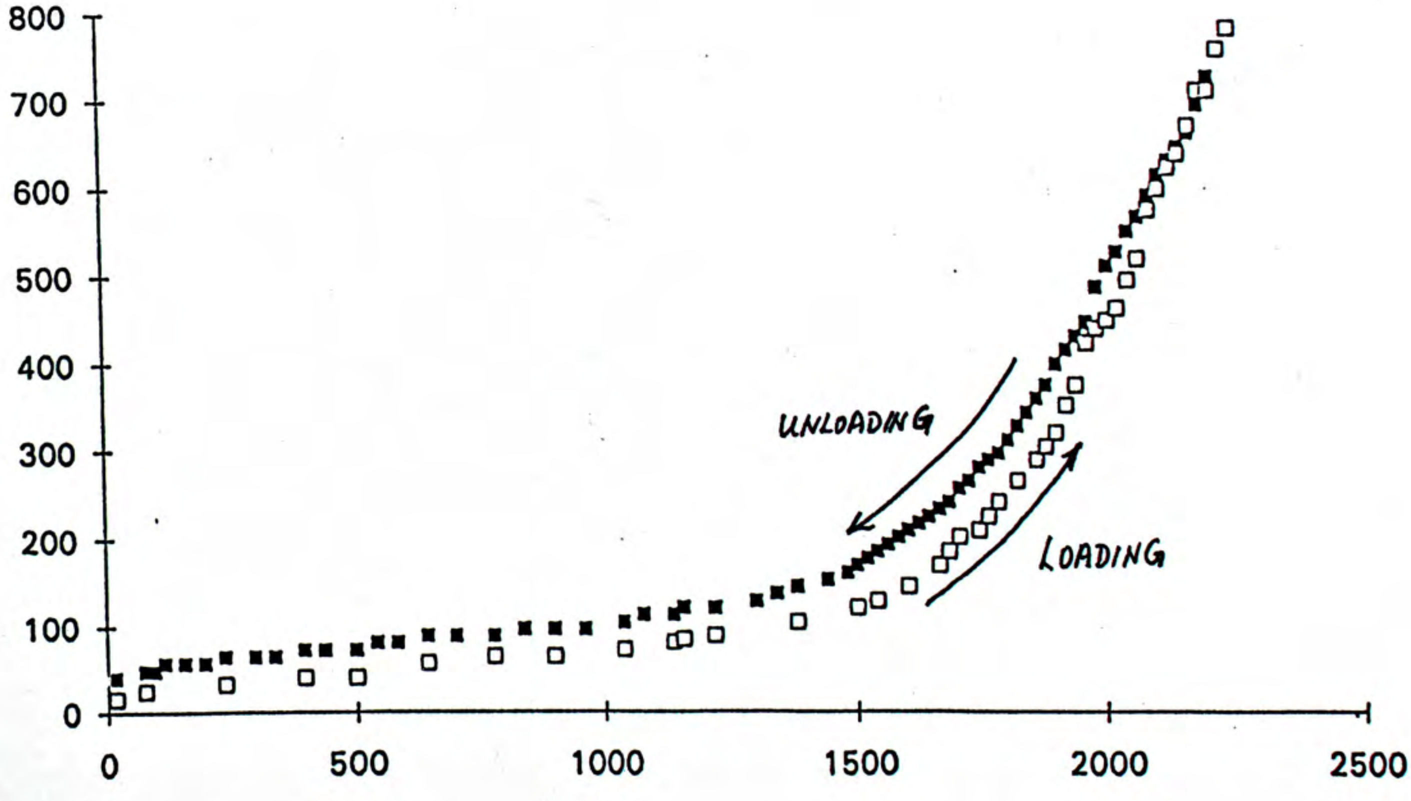

Fig. 4 The calibration curve FSR (voltage/mV vs force/N)

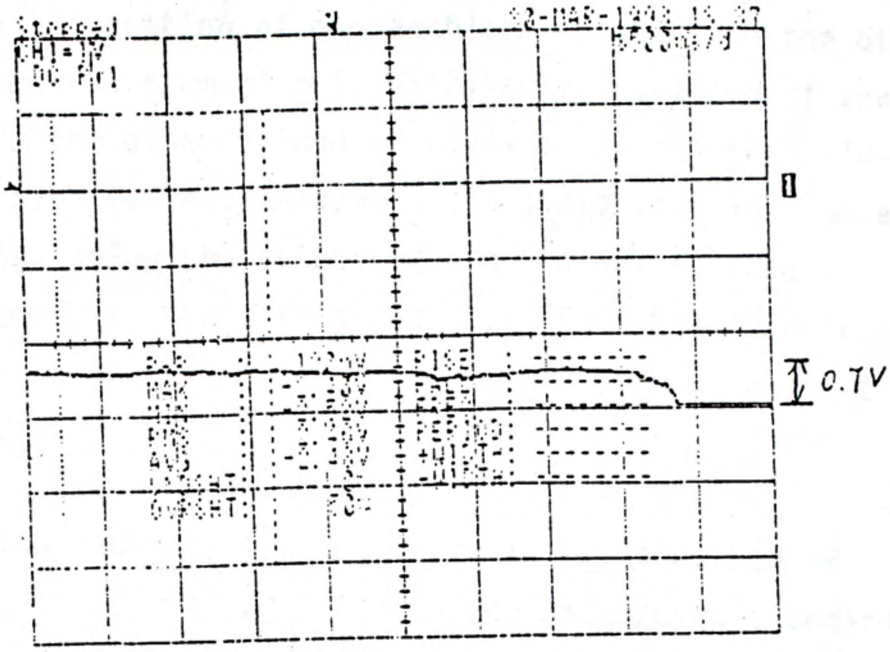

Fig. 5 An illustration on the oscilloscope display when the FSR is put under the splint at the MCP trough

APPENDIX V

Instruction Guide on the Penny & Giles Electrogoniometer

1.0 Penny and Giles 'M' series twin axis goniometers permit the simultaneous measurement of flexion/extension and abduction/adduction. Referring to figure 1, rotation of one endblock relative to the other around XX gives an output from plug 1. Similarly, rotation of one endblock relative to the other around YY gives an output from plug 2 (identified by the blue cable). Assuming the goniometer is mounted correctly as outlined below the output of the two channels is independent of linear displacements along axis ZZ. It should be noted that rotation of one endblock relative to the other about axis ZZ cannot be measured.

2.0 Due to the wide range of applications, a single method of attachment cannot be recommended. Experience has proven standard adhesive medical tapes to be an excellent method in the majority of cases. For long term accurate results it is suggested that double sided adhesive tape is employed between the endblocks and skin, and single sided adhesive tape is laid over the top of the endblocks. The interconnect lead should also be taped down near the goniometer since rapid movements may cause the goniometer to become detached.

3.0 All designs of electrogoniometers require fixation to the skin surface but the skin surrounding a joint will move relative to the underlying skeletal structure. The high flexibility of the Penny and Giles goniometer provides a low stiffness which reduces the tendency to pull or distort the skin. For the most accurate results, it is recommended that trial measurements are performed in order to locate areas where skin motion is a minimum.

4.0 The goniometer measuring element is housed within the protective spring and utilises strain gauge techniques. To prolong its life the following should be noted:-

4.1 The minimum permissible radius of bend for any M series goniometer is 18 mm (see figure 2). No parts of the measuring element should be subjected to a bend radius smaller than this at any time.

4.2 Under no circumstances should the goniometer be removed from the subject by pulling on the measuring element and protective spring. The endblocks must be removed individually and carefully making sure that the minimum permissible bend radius is not exceeded, particularly where the measuring element enters the endblocks.

5.0 CONNECTION OF GONIOMETERS TO PENNY AND GILES INSTRUMENTATION

5.1 Use one of the following leads:-

Type Number	Length (mm)
C500	500
C1000	1000
C1500	1500

5.2 Connect the 4 pole silver plug to the instrument ensuring that the red marks on the plug and socket are aligned, and push the plug until it engages with a click.

5.3 The plug is of a self-latching design and cannot be disconnected by pulling on the cable.

5.4 To remove the plug hold the outer release sleeve on the side which is machined for easy grip and pull until it disengages.

5.5 Push the black socket on the free end of the interconnect lead onto the mating black plug of the goniometer ensuring that they are polarised correctly be matching the red dot on the plug with the red dot on the socket of the electrogoniometer.

6.0 In certain applications when mounting the goniometer across the joint, (for example when measuring flexion/extensions of the wrist as shown in figure 5b), the centre of rotation of the goniometer measuring element does not coincide with the centre of rotation of the joint. As the joint moves through a determined angle the relative linear distance between the two mounting positions will change. To compensate for this, all M series goniometers are fitted with a telescopic endblock which permits changes in linear displacement between the two endblocks along axis ZZ without the measuring element becoming overstretched or buckled (refer figure 3). In the free or unstretched position the distance between the two endblocks is L1. If a light force is applied pushing the endblocks away from each other this length will increase to a maximum of L2. When the light force is removed the distance between the two endblocks will automatically return to L1.

The position of the slider can be seen at any time through the window positioned on the telescopic endblock. This has several advantages:

6.1 Improved accuracy of the goniometer.

6.2 Enables the goniometer to be worn comfortably undetected under normal clothing.

6.3 Reduces the tendency for the position of the goniometer to move relative to the underlying skeletal structure.

6.4 If a light force is now applied pushing the two endblocks linearly towards each other the only way the distance L1 can decrease in length is by the measuring element bucking as shown in figure 4. This buckling in certain circumstances may be detrimental to the accuracy of the goniometer and the following attachment instructions are provided for the most commonly measured joints to ensure that it does not occur in practice.

003

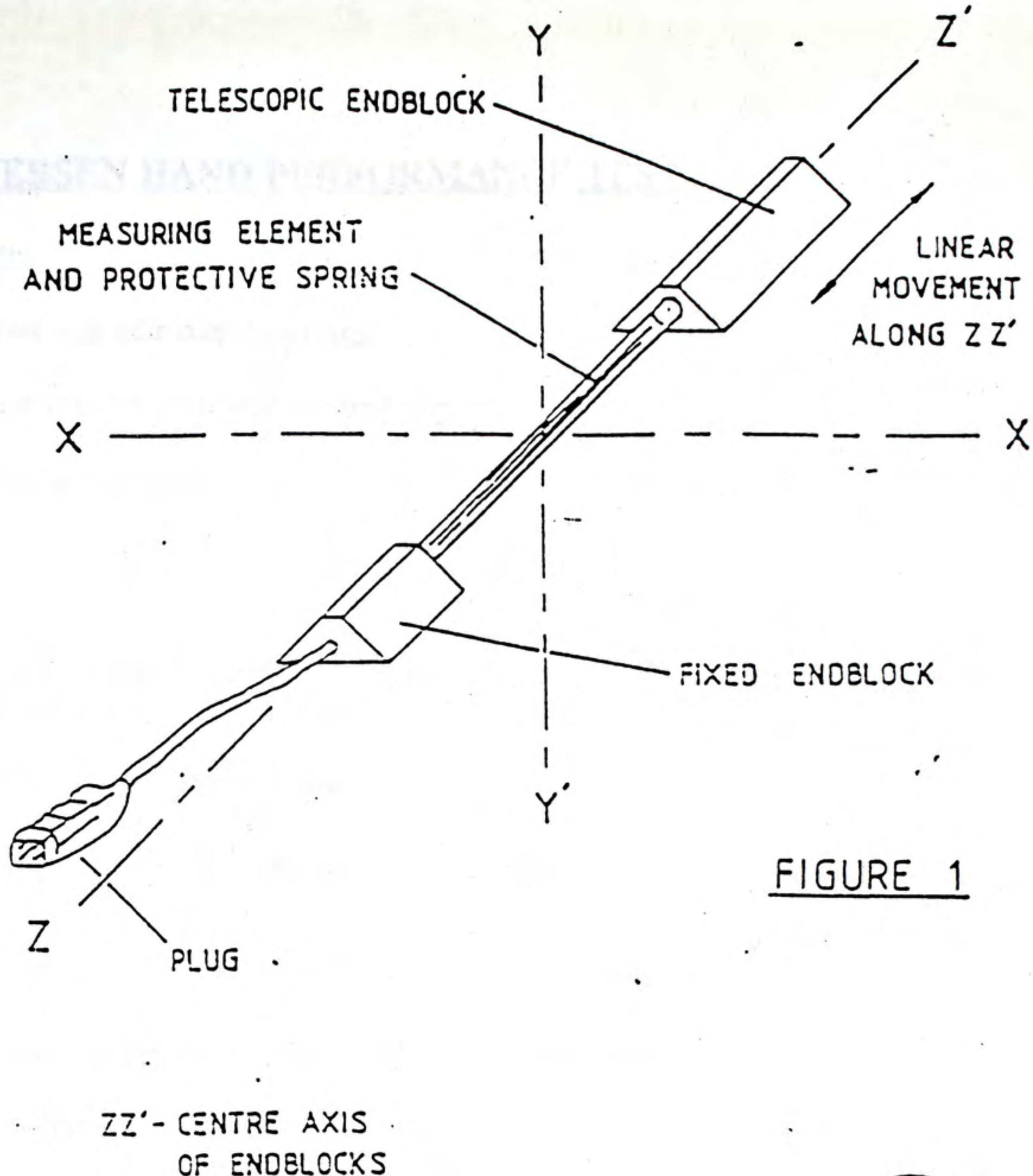

FIGURE 1

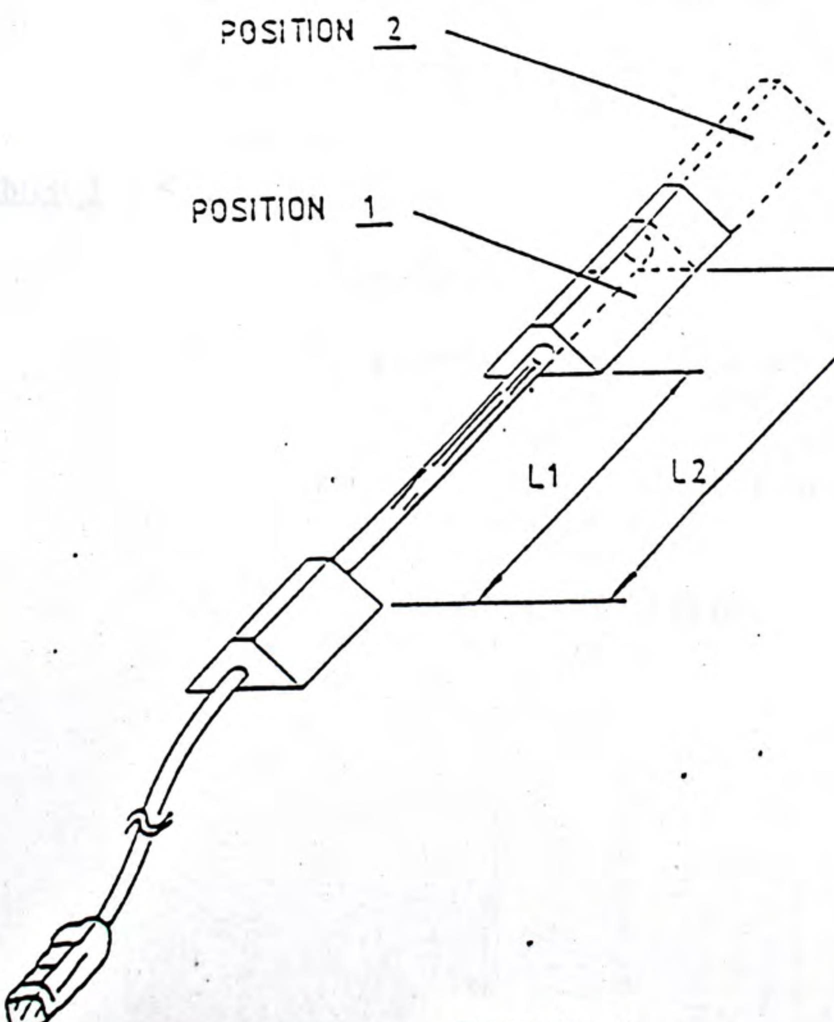

FIGURE 2

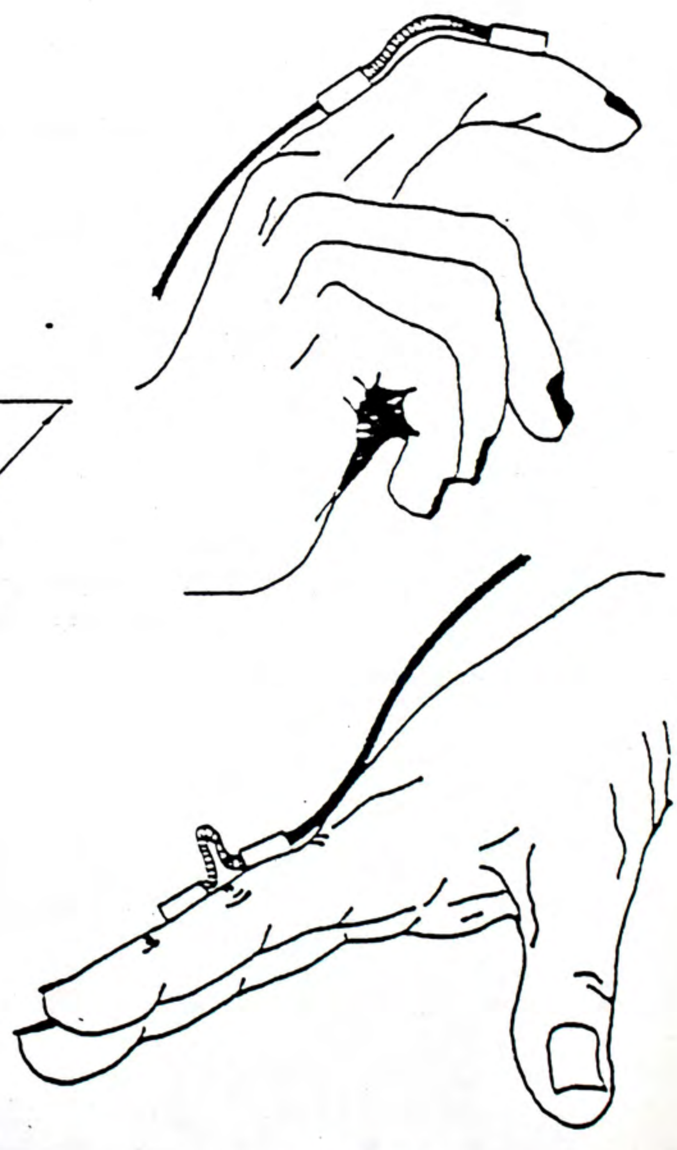

FIGURE 3

APPENDIX VI

JEBSEN HAND PERFORMANCE TEST

Instructions & Reminders :

1. Test non-dominant hand first.
2. Subtests are presented in same sequence each time.
3. Subject is seated.

Subtest 1 : Writing

1. Card is placed face down and is turned over by the examiner with an irmediate command to begin.
2. Write only, need not print.
3. Use different sentences, each time.

Subtest 2 : Card Turning

1. Cards are placed in a horizontal row 2 inches apart.
2. Each is oriented vertically, 5 inches from the edge.
3. No accuracy of placement is necessary.
4. Start with the card on the extreme right first (when testing, left hand).
5. Subject may turn them over in any way.

Subtest 3 : Small Objects

1. Empty can is placed directly in front, 5 inches from the edge.
2. The arrangement of the objects are :
   2 paper clips (oriented vertically), 2 bottle caps (inside of the cap facing up), 2 pennies, Empty can
   in a horizontal row to the left of the can (when testing left hand), 2 inches apart.
3. Start with the paper clips first.

Subtest 4 : Simulated Feeding

1. Kidney beans are placed on the board, which is clamped 5 inches from the edge.

2. Beans are oriented to the left of centre (when testing left hand) and touching the upright of the board 2 inches apart.

3. The empty can is placed centrally in front of the board.
i.e. on the desk

4. Begin with the bean on the extreme left (when testing left hand).

Subtest 5 : Checkers

1. Checkers are placed in front of and touching the board, clamped 5 inches from the edge.

2. Two on each side of the centre a 0000 configuration
i.e. touching each other

3. Stack the checkers on the board, one on top of the other.

4. The forth checker need not stay in place.

5. Begin with any checker.

Subtest 6 & 7 : Large Objects

1. Cans are placed in front of the board, which is clamped 5 inches from the edge, 2 inches apart.

2. Open end of the can is faced down.

3. Begin with the one on extreme left (when testing left hand).

積臣手部功能測驗

測 驗 一

你需唔需要戴眼鏡? 如果要, 請戴上.

用左手拿著枝筆, 在這張咭上面有一句子[指著張咭]

當我翻轉張咭話開始時, 你就盡快而清楚用手抄寫

這句子. 你明唔明白?

準備好未? 開始!

現在用右手再做一次, 我俾過另外一句子你寫.

準備好未? 開始!

積臣手部功能測驗

測 驗 二

將左手放在桌上. 當我話開開始時,你就盡快用左手翻轉這些咭. 每次只准翻轉一張. 由最右面的咭開始.

你可以用任何方法翻轉這些咭.

你明唔明白? 準備好未? 開始!

現在用右手再做一次, 由最左面的咭開始.

準備好未? 開始!

積臣手部功能測驗

測 驗 三

將左手放在桌上，當我話開始時，你就用左手盡快將這些物件逐一放在罐內，由這件開始（指著最左面的萬字夾），你明唔明白？

準備好未？開始！

現在用右手再做一次，由最右面的萬字夾開始，你明唔明白？準備好未？開始！

積臣手部功能測驗

測 驗 四

用右手拿著隻匙，當我話開始時，你就盡快撈起
這些豆放在罐內［指著最左面的罐］，你明唔明白？
準備好未？開始！

現在用右手面做一次，由這些豆開始［指著最右的罐］
準備好未？開始！

積臣手部功能測驗

測 驗 五

將左手放在桌上，當我話開始時，你就用左手盡快

一隻一隻砌起這些棋子在前面的板（示範）。

你可以隨便拿起一隻開始。

你明唔明白？準備好未？開始！

現在用右手再做一次，準備好未？開始！

積臣手部功能測驗

測 驗 六

將左手放在桌上. 當我話開始時, 你就用左手拿起

這些罐放在前面的板上, 好似這樣[示範].

由最左面的罐開始. 你明唔明白?

準備好未? 開始!

現在用右手重複一次, 由最右面的罐開始.

你明唔明白? 準備好未? 開始!

積臣手部功能測驗

測 驗 七

現在用這些較重的罐重複一次, 將左手放在桌上.

當我話開始時, 你用左手拿起這些罐放在前面

的板上. 由最左的罐開始. 你明唔明白?

準備好未? 開始!

現在用右手重複一次, 由最右的罐開始.

你明唔明白? 準備好未? 開始!

Appendix VII

Consent Form

Title of Research Project

The effect of corrective splintage on flexion contracture of rheumatoid fingers

Objective

To assess the effectiveness of a dynamic and a static finger extension splint on the flexion contracture of rheumatoid fingers

Procedure

The experimental procedure will involve the subject in two pre-experimental assessments, one conducted in the initial assessment, and one conducted six weeks before the implementation of a standardised splint programme. The subject will be involved in a post-experimental assessment six weeks after the splint programme.

The three assessments are standardised including assessment of active range of motion on the affected finger joints, assessment of grip strengths (power grip, pinch grip, chuck grip and lateral pinch grip), assessment of hand functions by the Jebsen Hand Function Test and pain assessment by a visual analog.

The splint programme is different in group 1 and group 2 clients. For group 1 clients, the dynamic finger extension(capener) splint is to be worn alternately at an interval of 2 hours on and 2 hours off. It is to be removed during night rest. A maximum of 8 hours wear per day is recommended.
For group 2 clients, the static finger extension(belly gutter) splint is to be worn at night rest only for 8 hours per day. It is to be removed during the day.

Following the six week period, the subject will undertake another assessment identical to that of the initial assessment.

DECLARATION

I ______________________________ fully understand the procedures of the research project mentioned above and am willing/not willing to participate on a voluntary basis.

Signature:______________________________

Date:______________________________

同 意 書

研究項目

手指托對風濕病人手指關節屈曲變形之效用.

研究目的

確定手指托對減少風濕病患者之手指關節變形的功效.

研究程序

（一） 事前檢驗

每位志願參加此項研究工作的病人需接受
下列四項測試.
以確定病人接受手托療程以前的手部功能.

a. 手指關節活幅度.
b. 手指握力.
c. 手部功能測試 （積臣手部測驗 ）
d. 痛楚評估.
*（此項測試需在佩帶手托六星期前及即時進行 ）

（二） 手托療程

每位參加此項研究的病人需依照治療師之指示
佩帶手托之程序及方法,維期六星期,
不得有任何間斷,如因其它原因,
不能佩帶者需立刻通知治療師.

（三） 覆驗

完成六星期之療程之後,病人將會再一次接受第一項
的四樣檢查, 以確定手托療程對病人的療效.

志 願 書

本人________________________完全明白呎整個研究
的目的及程序,並 願意 / 不願意 參加此項研究.

________________ ________________
日 期 簽 署

Appendix VIII

The Chinese Universtiy of Hong Kong
Faculty of Medicine
Department of Orthopaedics & Traumatic Surgery

Arthritis Assessment Form

Name:________________ Sex/Age:_________ Client no.:__________

Diagnosis:_____________ Date of onset:_____________

Date started study:________________ Occupation:____________________

Hand Dominance:____________ Tel.no:______________

Address:____

Initial Assessment:_____________________

A. Clinical presentation

X-Ray classification:

Swelling

Morning Stiffness

Deformities

Medical History:

B. Social Background

C. Financial Status

D. Personaility

Pain Score

Initial Asst. ( )	Pre-splint ( )	Post-splint ( )

Physical Assessment

I. Grip strength

Grip strength	Asst I	Asst II	Asst III	Remarks
Power grip (R)				
Power grip (L)				
Pinch (R)				
Pinch (L)				
Chuck (R)				
Chuck (L)				
Lateral Pinch (R)				
Lateral Pinch (L)				

II. Jebsen Hand Function Test

Items	Asst I	Asst II	Asst III	Remarks
1 Writing -Right				
-Left				
2 Card turning -Right				
-Left				
3 Small objects -Right				
-Left				
4 Simulated feeding-Right				
-Left				
5 Chess stacking -Right				
-Left				
6 Light can -Right				
-Left				
7 Heavy can -Right				
-Left				
Total -Right				
-Left				

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American Society for Surgery of the Hand: The Hand -examination and diagnosis, Aurora, Colo, 1987

Jebsen RH and other: An objective and standardised test of hand function, Arch Phys Med Rehab. 50:311, 1969

Joint Range of Motion

Date of initial assessment: ____________________

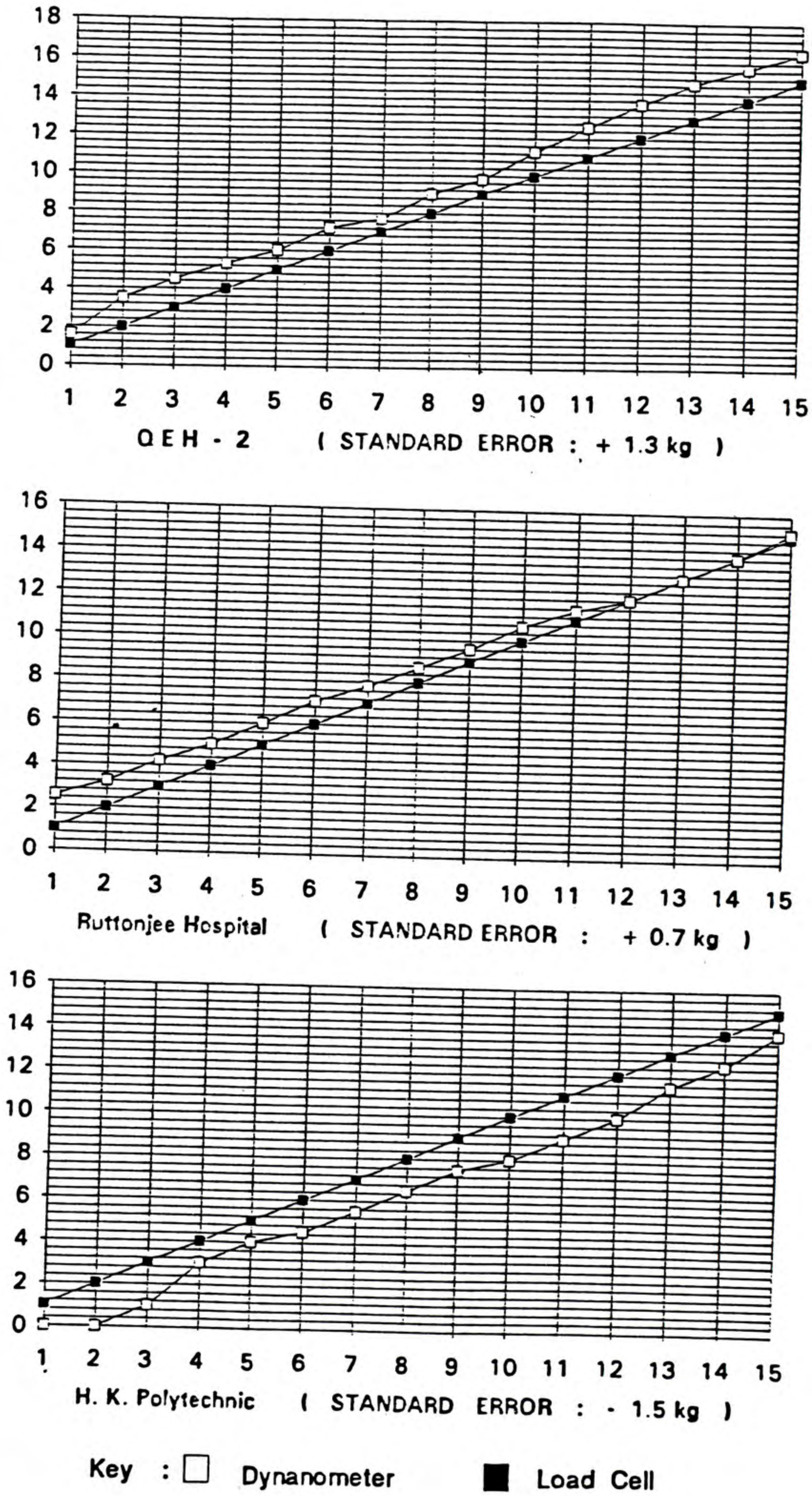
Finger	Right	Asst I	Asst II	Asst III	Left	Asst I	Asst II	Asst III
Thumb	MP				MP			
	IP				IP			
Index	MCP				MCP			
	PIP				PIP			
	DIP				DIP			
Middle	MCP				MCP			
	PIP				PIP			
	DIP				DIP			
Ring	MCP				MCP			
	PIP				PIP			
	DIP				DIP			
Little	MCP				MCP			
	PIP				PIP			
	DIP				DIP			

Remarks: ____________________

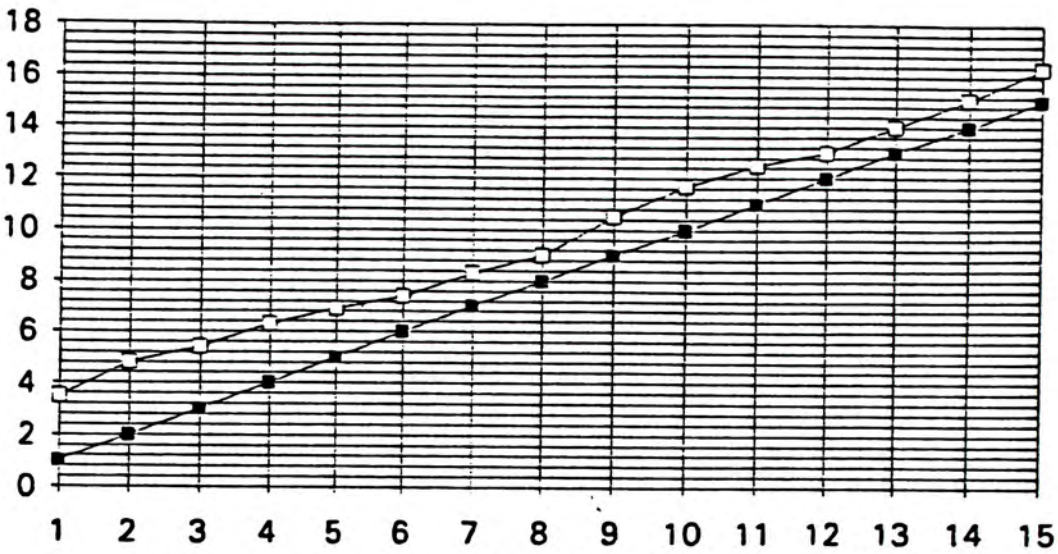
arthrit.as2

APPENDIX IX

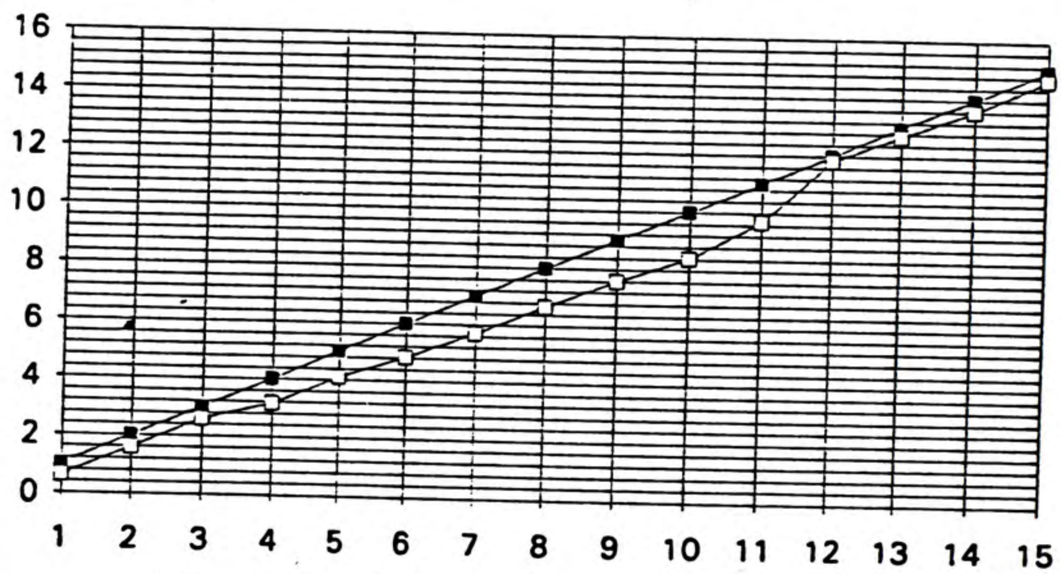
Graphical presentation of readings of each dynamometer from the load cell



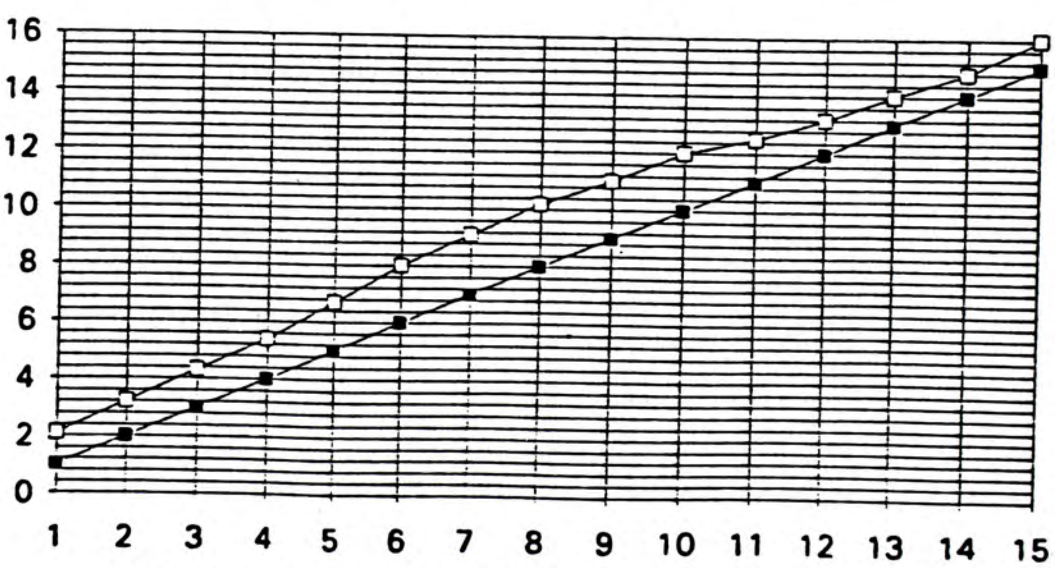
Graphical presentation of readings of each dynamometer from the load cell



K W H - 1 (STANDARD ERROR : + 1.65 kg)



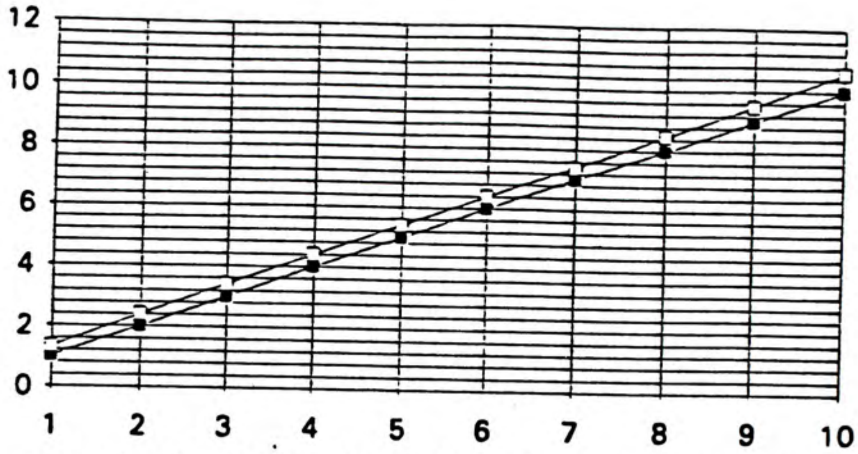
Q E H - 1 (STANDARD ERROR : - 0.82 kg)



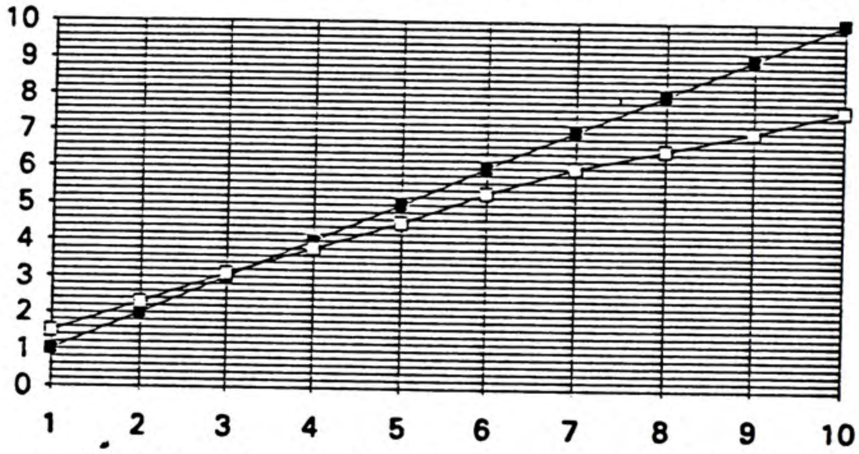
K W H - 2 (STANDARD ERROR : + 1.5 kg)

Key : □ Dynamometer ■ Load Cell

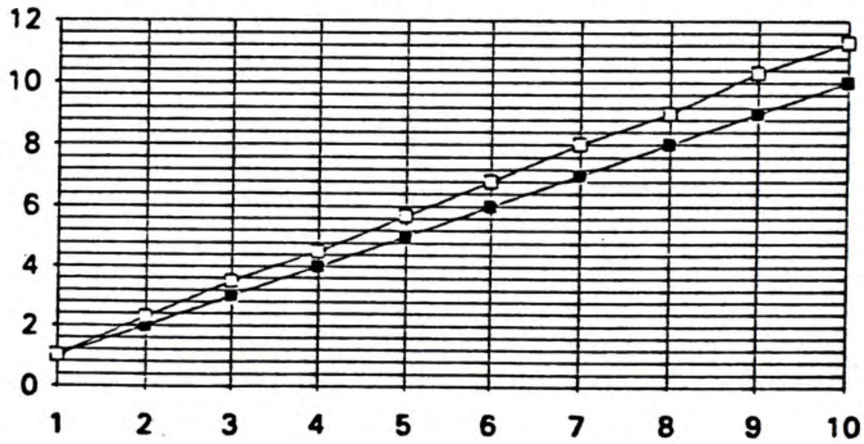
Graphical presentation of the deviation of each pinch gauge from the load cell



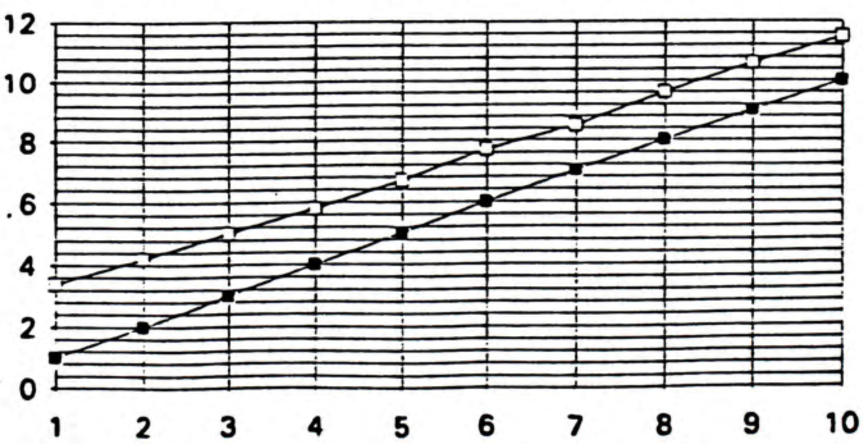
Ruttonjee Hospital (STANDARD ERROR : + 0.43 kg)



H. K. Polytechnic (STANDARD ERROR : - 0.74 kg)



QEH-1 (STANDARD ERROR : + 0.74 kg)



QEH-2 (STANDARD ERROR : + 1.8 kg)

Key : □ Pinch Guage ■ Load Cell

Appendix X

Procedure for the fabrication of the belly gutter splint

Materials
Non-perforated thermoplastic materials (orfit 2mm, aquaplast 2mm)
Heat gun
Heat pan
velcro straps, padding material
latex

Procedure
1. Trace the outline of the finger with flexion contracture on a piece of paper.

2. Sketch the pattern of the splint to be fabricated to allow more materials at the PIP joint. Mark the PIP joint level.

3. Fit the paper pattern onto patient's finger, make suitable adjustment where necessar.

4. Draft the paper pattern onto the splinting material and cut out the pattern.

5. Heat the whole piece of the splint pattern on a heat pan with suitable moulding temperature.

6. Mould the splint onto the patient's finger. Then mark the PIP joint level on the splint.

4. Use a heat gun and spot heat the PIP joint level of the splinting material until the middle part is mouldable again.

5. Use the pad of your thumb to push from inside of the PIP joint level and make a doom out like a belly.

6. Fit the splint onto the patient's finger again.

7. Measure the circumference of the splint at the PIP joint level and cut out the accurate length of velcro strap.

8. Glue the strap onto the splint at the PIP joint level. A soft pad is added on the strap at the dorsum of the PIP joint to minimise friction.

9. Apply the finished splint onto the patient's finger. Recheck the pressure after 15 minutes.

10. The splint is adjusted for more finger extension at three week interval during the splinting period. Small adjustment could be made to improve comfort.

Note: **The concept of the belly gutter splint is by using the belly at the PIP joint level, the splint is able to accomodate the flexed finger. And as the flexion contracture improves, the velcro strap can be tightened to bring the splint into the alignment of the finger since the belly at the PIP joint level is flexible. Therefore, there is no need for constant adjustment.**

<u>Procedure for the fabrication of the capener splint</u>

<u>Materials</u>

Non-perforated thermoplastic materials (orfit 2mm, aquaplast 2mm)
Heat gun
Heat pan
a pair of spring wire approximately 16 cm long with the spring coil in the middle(wire circum: 19 s.w.g., coil diameter: 0.8 cm)
latex, padding material
a pair of pliers, wire cutter

<u>Procedure</u>

1. Measure the circumference of the proximal phalanx(c) and the length between the web and the PIP joint level(l). Cut out a rectangular piece of splinting material with length(l) and width (c).

2. Dry heat the two sides of the rectangular piece of splinting material and mould it onto the pair of spring wire with the coil on the same direction.

3. Bend down the two spring wires at a right angle and another turn of 90 degrees to fit the contour of the palmar side of the MP joint. Until the wire reaches the distal palmar crease, the two wires are bent at 90 degrees laterally. Leave 0.3 cm behind for anchorage and cut off the remaining wire.

4. Measure the size of the palmar pad of the capener splint from the base of the MP level to the distal palmar crease.

5. Cut two pieces of same pattern of the splinting material.

6. Dry heat the two splinting pieces and then wrap the two metal spring wire in the middle for anchorage. This forms the proximal trough of the capener splint.

5\. Measure the length of the spring wires from the coil to the DIP joint. Then bend the two wire back to form a small loop. Cut off the remaining length of the wires.

6\. For the distal trough, measure the circumference of the DIP joint and the length is approximately 1 cm, then cut the same size of splinting material out.

7\. The splint is heated again and mould at the palmar side of the DIP joint with two sides wrap out to hold the spring wire.

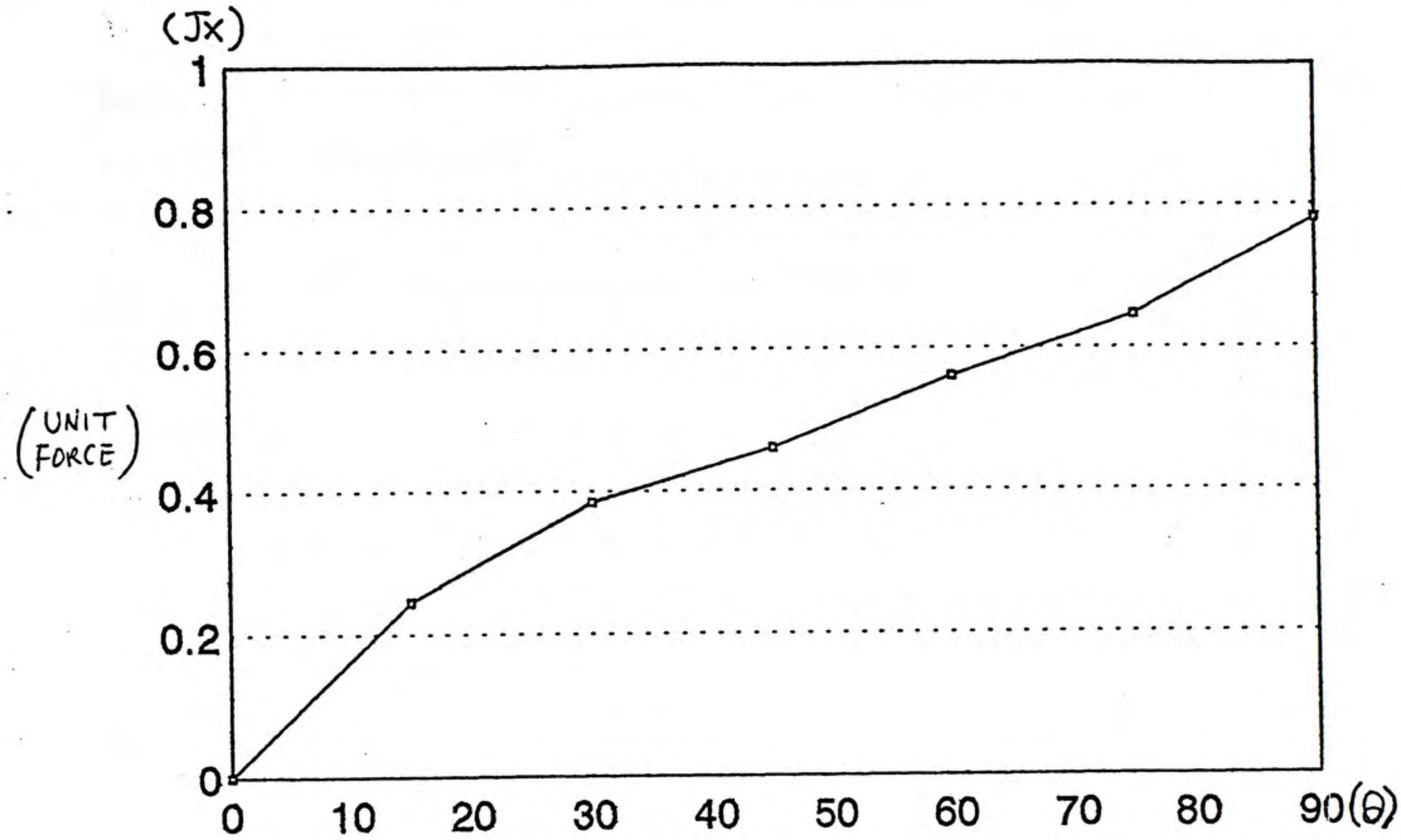
8\. Fit the splint onto the patient's finger again.

9\. Apply the finished splint onto the patient's finger. Recheck the pressure after 15 minutes.

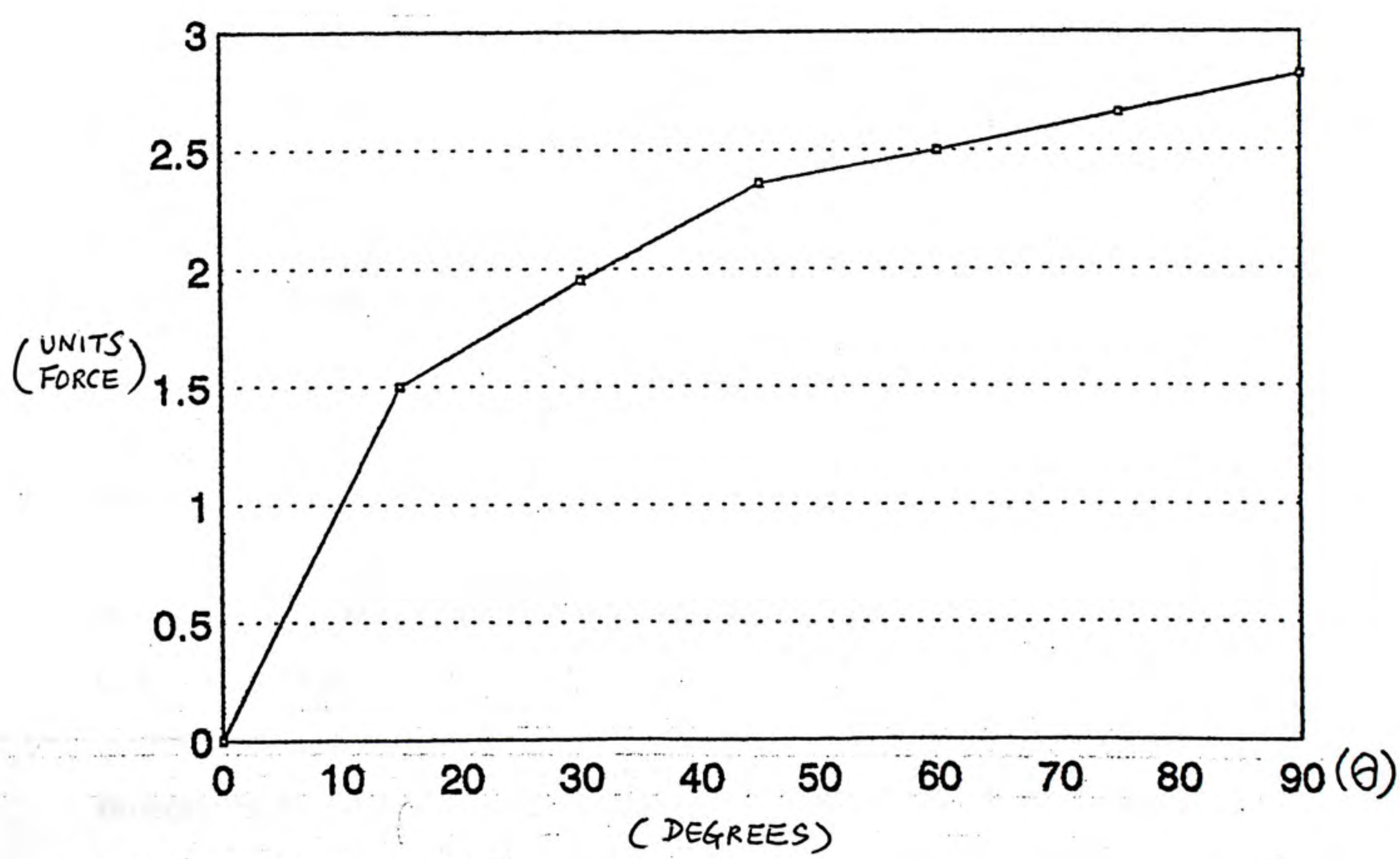
10\. The splint is adjusted for more finger extension at three week interval during the splinting period. Small adjustment could be made to improve comfort.

Appendix XI

Graphs illustrating the Relationship of Joint Compression Force (Jx) and the Flexion Contracture Angle (0)



The Capener splint



The Belly Gutter splint

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